6 POTENTIAL ENVIRONMENTAL EFFECTS OF OIL AND GAS DRILLING ON GREAT LAKES RESOURCES

A variety of environmental effects have been associated with oil and gas projects in the United States and abroad. The likelihood, nature, and magnitude of these effects depend on a variety of factors, including:

- The specific phase of the oil and gas development (exploration, well completion, and production);
- The specific location of the energy development activity;
- The nature and condition of the environmental resources present in surrounding areas;
- The nature and extent of human development and activities (including land and water use) in the surrounding areas;
- The technology employed to extract and process the oil and gas;
- The disposal of waste materials produced during drilling and extraction; and
- The permit stipulations and mitigation measures that could apply to oil and gas production at a specific location.

Figure 6.1 identifies the activities associated with each phase of oil and gas development that could result in environmental effects within the Great Lakes Basin; it is these activities that will be considered in greater detail in the evaluation of environmental effects of oil and gas drilling in the Great Lakes. Each of the activities identified in this figure may generate one or more environmental stressors that could affect natural resources and human activities. An environmental stressor is defined as a physical, chemical, or biological entity that can induce an adverse response (EPA 1997; 1998). For this evaluation, physical stressors include temperature, noise, fugitive dust, turbidity, as well as activities that physically alter a habitat. Chemical stressors are substances that elicit adverse responses from exposed biota and may thereby alter a designated use of a resource. Examples of chemical stressors include oil- and gas-related compounds, dissolved oxygen, and pH. Biological stressors include disease agents and introduced species that could result in adverse population and higher-level trophic effects. Figure 6.2 shows the general types of stressors associated with oil and gas development. In addition, the presence of oil and gas infrastructure and activities may elicit adverse reactions in nearby human populations.

The identification of potential site-specific environmental effects is beyond the scope of this report. Instead, this report focuses on the nature and extent, rather than on the magnitude, of potential effects that may be incurred by environmental resources (including impacts on land and water use by humans) with any future development of the oil and gas reservoirs

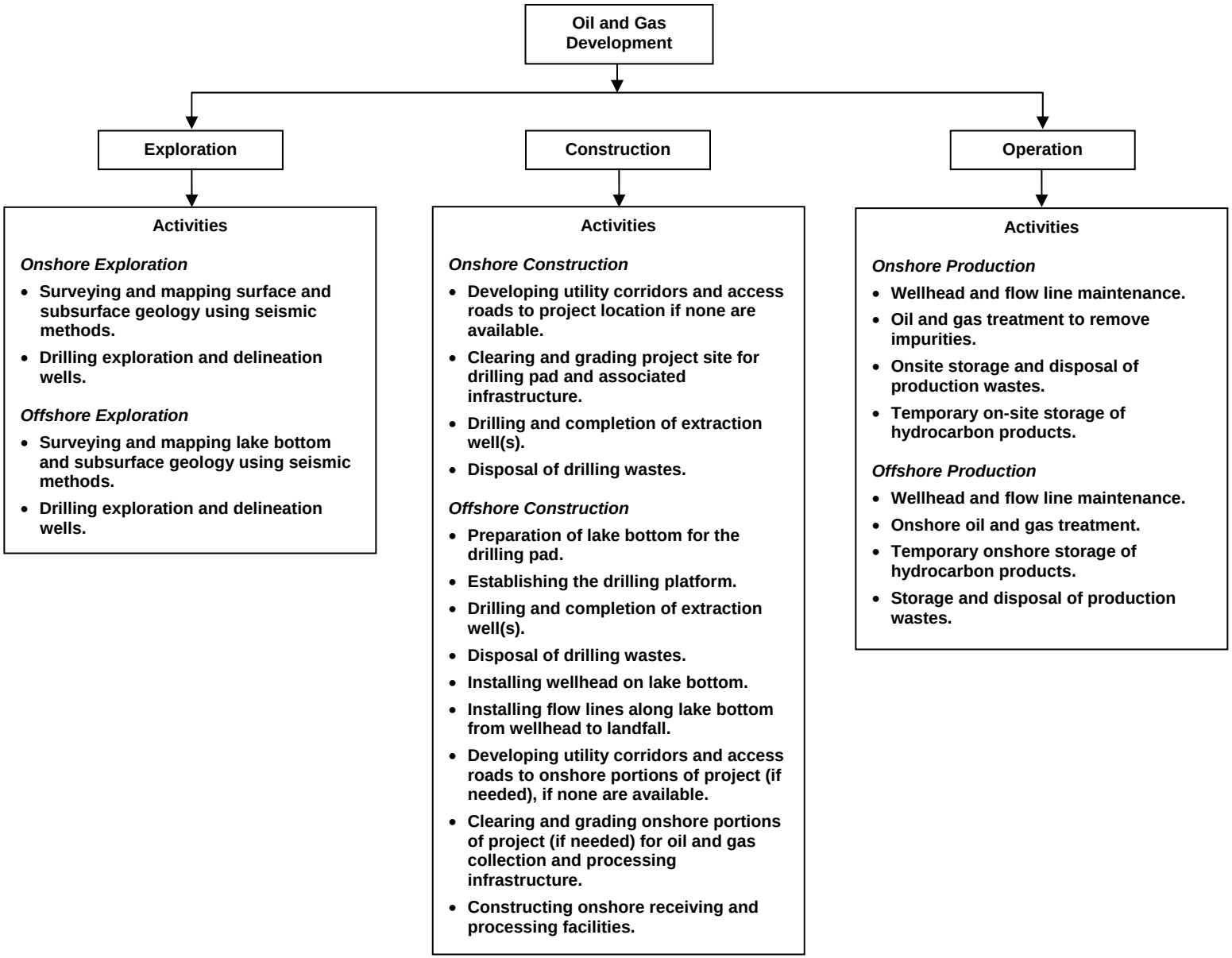

FIGURE 6.1 Activities Associated with Different Aspects of Oil and Gas Development
("Onshore" includes facilities with onshore extraction, processing, and storage facilities. "Offshore" includes facilities with offshore extraction wells and onshore pipelines, and processing and storage facilities.)

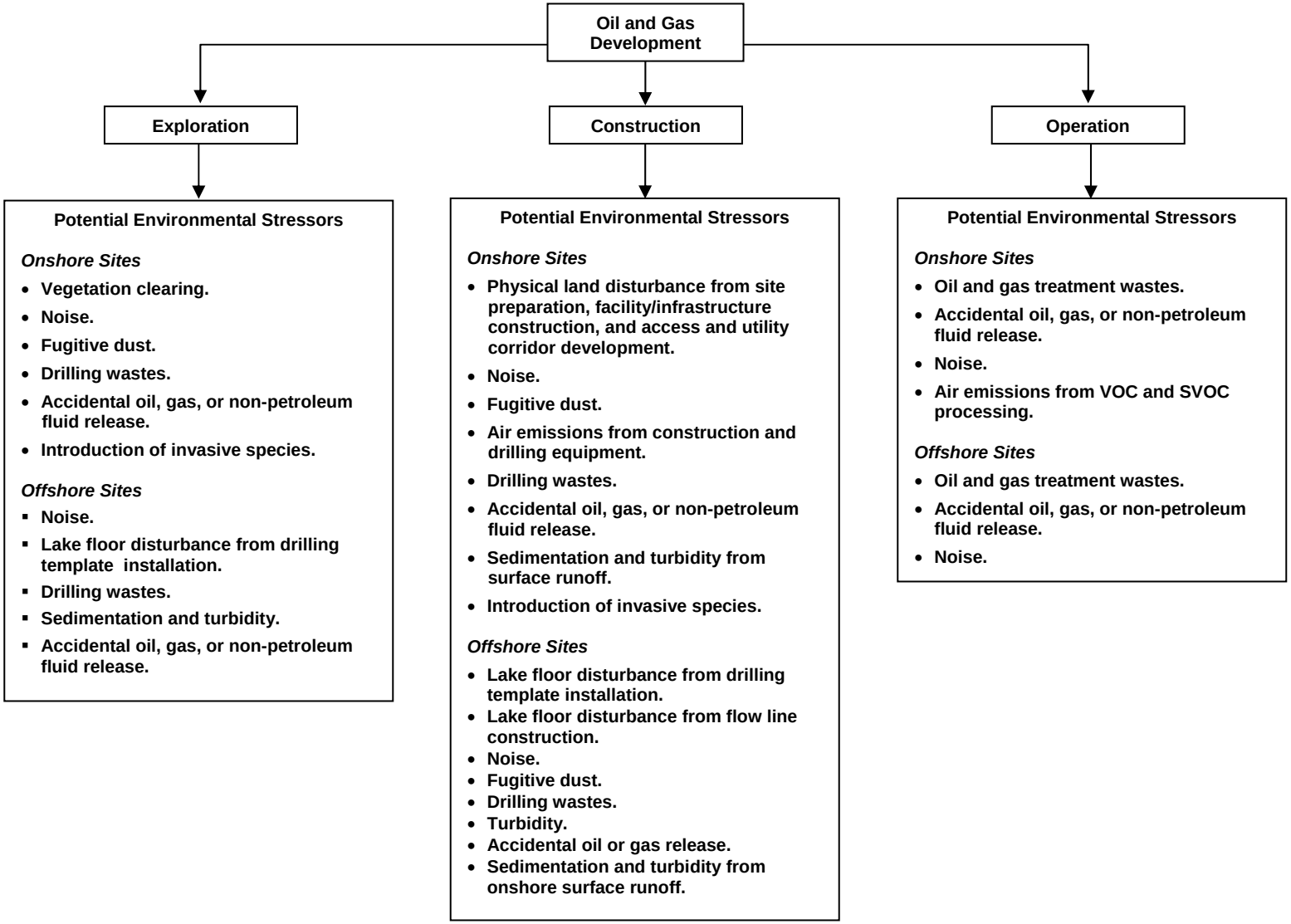

FIGURE 6.2 Environmental Stressors Potentially Associated with Different Aspects of Oil and Gas Development
("Onshore" includes facilities with onshore extraction, processing, and storage facilities. "Offshore" includes facilities with offshore extraction wells and onshore pipelines, and processing and storage facilities.)

beneath the Great Lakes. Thus, the following discussions apply to those areas of the Great Lakes with known or suspected oil and gas systems — the areas with the highest likelihood of undergoing future oil and gas development — and the resources and land and water uses in those areas.

It is outside the scope of the study and this report to address the magnitude of any potential site-specific effects because these are a direct function of the following:

- The specific location where oil or gas exploration and development is occurring;
- The size of the production site;
- The density of production sites within a specific area;
- The nature and condition of the environmental resources present in the project area;
- Land and water use in the project area;
- The regulatory requirements that would govern the project at that location;
- The physical and chemical characteristics of petroleum and associated petroleum fluids;
- The nature and magnitude of any accidental release of oil, gas, or drilling and post-extraction processing wastes; and
- The mitigation measures that would be required or could be included for the project.

Because this study does not address a specific Federal action or location with the Basin, much of the above information could not be identified.

6.1 MITIGATING FACTORS AFFECTING THE MAGNITUDE OF POTENTIAL ENVIRONMENTAL EFFECTS

The following sections (Sections 6.2 through 6.7) discuss the types of environmental effects that might be incurred during the exploration, construction, and operation phases of oil and gas development. Potential effects (associated with the stressors identified in Figure 6.2) to natural and cultural resources, land and water uses, and human health are associated with three primary activities: (1) exploration; (2) construction of wells, pipelines, and associated infrastructure; and (3) accidental releases of oil or gas or drilling, production, and processing wastes. The likelihood and severity of potential adverse effects will be influenced by a variety of mitigating factors. These factors include:

- Existing land and water setting and use;
- Facility design, size, siting, and density;
- Availability of existing infrastructure;
- Use of good engineering practices;
- Project scheduling;
- State siting restrictions;
- State and Federal regulations and restrictions governing activities potentially affecting protected species and other natural resources; and
- Existing spill response programs and requirements.

Consideration of these factors during all phases of an oil or gas development may prevent or greatly reduce potential environmental effects of oil and gas exploration, construction, and operation. The role that each of these factors may have on mitigating potential environmental effects is discussed in the following sections.

6.1.1 Existing Land and Water Use

The potential for adverse effects on environmental resources will be strongly dependent on the setting of the area and its existing land and water uses where a well may be developed. For example, industrial areas will have few if any ecological resources or unique habitats that could be affected by construction or operation of oil and gas wells and pipelines, and no change in existing land use or potential for future land use would be expected with oil or gas development. In contrast, recreational areas may be expected to support considerable ecological resources that could be affected by oil or gas development. Similarly, areas with predominantly recreational water use will likely also contain quality ecological resources and may thus incur greater impacts than surface water areas in industrial or large urban settings.

6.1.2 Facility Design, Size, Siting, and Density

Careful consideration of facility design may minimize the likelihood and magnitude of potential environmental effects of a new oil or gas well and associated infrastructure. With proper design, seismic survey corridors, access roads, and infrastructure corridors may be routed to avoid sensitive resources. Similarly, incorporation of monitoring and mitigation measures, such as the use of measuring equipment to monitor atmospheric H_2S concentrations, may enhance accident identification and response times, thus reducing potential impacts to human health or the environment.

The size, siting, and density of wells may have a significant role in determining the magnitude and extent of environmental effects that may occur with an oil or gas development. Oil or gas well sites (including pumping unit and collection and processing equipment) may vary considerably in size, and the greater the size of the site, the more land or lake bottom must be disturbed and habitat removed. The size of a facility is affected, in part, by the depth of the hydrocarbon deposits to be developed and the geographic extent of the reservoir. Deeper wells need bigger pads, pumps, and other drilling and well equipment and thus require greater surface disturbance. The width and length of any new pipelines, access roads, and utility corridors also affect the amount of habitat that may need to be disturbed in order to provide for these facilities.

Siting an onshore facility to avoid nearshore sensitive or rare communities, habitats, or known cultural resources should generally be possible, because slant drilling well locations may be as far as 2.5 mi [4.02 km] from the shoreline. However, avoidance may be difficult in locating pipeline corridors from offshore drilling sites to landfalls in areas with extensive nearshore habitats (e.g., where beach or dune communities extend for miles along the shoreline). Siting new wells and associated infrastructure away from recreational areas, such as state parks and beaches, would reduce the potential for impacts on recreational land and water use. Development in highly visible recreational areas, such as public beaches, along hiking or biking trails, or near heavy-use commercial fishing docks would result in adverse aesthetic impacts. Ideal locations from a visual standpoint would be previously disturbed industrial sites.

The density of wells, which will depend in part on state siting regulations, that could be implemented in a new area would also directly affect the magnitude and extent of potential environmental effects. The greater the density of wells, the greater is the potential for adverse environmental effects such as habitat loss and fragmentation, or visual impacts on recreation and tourism. Depending on the land use, the density of wells may have relatively little or considerable impact on environmental resources. For example, fewer ecological, cultural resource, or recreational land use impacts would be expected with high well density in an industrial land use setting. However, a high density of wells within a more natural setting, such as forest land in northern Michigan, would likely result in considerably greater environmental impact due in part to greater loss of habitat, greater habitat fragmentation, and greater likelihood of affecting the recreational use of the area.

Current directional drilling technology allows for multiple wells to occur within a single bore hole, thereby reducing the numerical density of individual well pads within a given area. This also reduces the amount of land area (and associated construction impacts) that would be needed for the individual well sites.

6.1.3 Availability of Existing Infrastructure

Siting onshore wells or pipeline landfalls, pipeline and utility corridors, and access roads as close as possible (e.g., collocating) to existing roads, pipelines, and utility corridors may greatly reduce the amount of land disturbance that would be required for new construction, thereby reducing the disturbance or loss of wildlife habitat and the potential to affect sensitive or unique species or communities. Such siting may also reduce the potential for habitat

fragmentation as well as impacts to cultural resources and existing land use. The availability of existing infrastructure may be limited in the less developed areas of the Basin.

6.1.4 Use of Good Engineering Practices

Many of the potential effects discussed in this report are related to construction activities. The implementation of good engineering practices, such as the use of siltation fences to control surface runoff from construction areas, may reduce or eliminate the likelihood for, or magnitude of, some types of impacts. Examples of good engineering practices include:

- Employing proper well construction and completion practices (e.g., casing placement and cement);
- Grading cleared areas away from adjacent wetlands or surface waters to control sediment input;
- Controlling fugitive dust generation through the use of water sprays;
- Covering soil stockpiles with tarps to limit erosion and runoff during storm events;
- Maintaining equipment mufflers to limit noise disturbance of wildlife or nearby humans;
- Properly selecting culverts to maintain natural flows and allow for fish passage at all access road and pipeline stream crossings; and
- Restoring and revegetating disturbed soil areas to reduce erosion potential.

6.1.5 Project Scheduling

Some potential effects from new oil and gas development are associated with noise generated during exploration activities and during the construction of well sites, pipelines, access roads, and utility corridors. Noise and human activity during exploration and construction may disturb and adversely affect biota (such as nesting birds) or humans (such as tourists, beachgoers, hikers, or nearby residents). It may be possible to schedule construction activities to minimize such impacts. For example, construction may be scheduled to avoid the season when nearby colonial bird nest areas are active, to avoid the early morning and late afternoon periods when humans may be disturbed, or to avoid disturbing aquatic habitats during fish spawning periods.

6.1.6 State Siting Restrictions

Many of the Great Lakes states have regulations that govern the siting of gas and oil wells and pipelines. While these regulations vary among the states with regard to specific details, compliance with these regulations will reduce the potential for many of the effects identified in connection with construction of wells and associated infrastructure. For example, existing drill sites in Michigan are as close as 700 ft (213 m) from the shoreline (MESB 1997). Out of concern about potential impacts on wetland and other nearshore habitats and other natural resources, the Michigan DNR and Department of Environmental Quality have adopted oil and gas leasing regulatory changes that require a minimum 1,500-ft (457-m) setback from the Great Lakes coastline for directionally drilled wells and for new storage and treatment equipment and access roads associated with those wells. This setback may greatly reduce the likelihood of affecting coastal or nearshore habitats and recreation areas. Other restrictions address well density. For example, Ohio requires a minimum spacing of one well per 20 acres (8 ha), while New York prohibits wells from being drilled closer than 660 ft (183 m) from a lease boundary line or closer than 1,320 ft (402 m) from another producing well.

6.1.7 State and Federal Regulations Governing Protected Species and Other Natural Resources

The ESA, as well as state regulations governing protected species, would likely play a major role in the siting of new oil and gas facilities in the Great Lakes. For example, the development and siting of new wells in Michigan may be especially influenced by the ESA and similar state regulations. The coastal and nearshore areas of the upper Lake Michigan region support a number of Federally listed species, as well as sensitive or unique habitats and communities. Oil or gas development in areas with these resources will require careful siting and design, and likely extensive mitigation during construction. While fewer listed species or sensitive or unique habitats may be encountered along the central and eastern basins of Lake Erie, similar siting and design considerations would apply if listed species or unique habitats and communities are present in the vicinity of a potential drill site. Areas with known species listed under the ESA could be off limits to oil and gas exploration or development. Similarly, CWA wetland regulations will preclude the placement of well sites within wetlands and affect the siting and design of facilities located adjacent to many wetlands. Pipelines, access roads, and utility corridors crossing wetlands will also likely be strongly affected by wetland regulations.

6.1.8 Existing Spill Prevention and Response Programs and Requirements

Of greatest concern with any new oil or gas development is the occurrence of an accidental spill or release. The magnitude and extent of environmental effects that would result from such an event will be related to the spill prevention and response programs that are in place within the Great Lakes states. In particular, the speed and effectiveness of a spill response will directly influence the subsequent environmental effects of the accident. A number of Federal and state programs and requirements are currently in place that are intended to facilitate rapid spill

notification, response, and cleanup. Application of and compliance with these programs and requirements will reduce the magnitude of potential effects that could occur in the event of a well or pipeline release.

The EPA is the lead Federal agency for responding to spills in inland waters and has developed a number of programs, measures, and requirements for preventing, reporting, and responding to oil spills. For example, the EPA Region 5 Oil Planning and Response Section has developed an Area-Regional Contingency Plan that identifies risks and resources for response and sets policies for Federal responders to follow specialized techniques, such as in situ (in place) burning of oil and chemical countermeasures. The plan encompasses all of the Great Lakes states except Pennsylvania and New York. To address site-specific concerns, EPA Region 5 has identified 20 subareas and developed, together with state and local governments, subarea response plans that address such localized issues as response jurisdictions, response tactics on specific waterways, and command structures during response actions. In addition, NOAA operates a Great Lakes spill response center in Ann Arbor, Michigan.

Fixed onshore and offshore oil well drilling facilities, oil production structures, and some pipelines must also comply with the SPCC Regulation (40 CFR Part 112), which requires owners or operators of regulated facilities to prepare and implement SPCC plans. These plans must identify:

- Operating procedures the facility implements to prevent oil spills;
- Control measures installed to prevent oil from entering navigable waters or adjoining shorelines; and
- Countermeasures to contain, clean up, and mitigate the effects of an oil spill that has an impact on navigable waters or adjoining shorelines.

Individual states also have spill response programs and requirements intended to identify and respond to accidental release as quickly as possible. For example, the Michigan Department of Environmental Quality Pollution Emergency Alerting System requires that well permitees notify the system within 8 hours of a spill or discovery of a release. In Indiana, all spills that have not been cleaned up or for which cleanup has not been initiated in compliance with state regulations must be reported to the Indiana Department of Emergency Management within two hours of discovery.

At locations with sensitive or important resources (such as nature preserves, drinking water intakes, and recreational beaches), spill prevention plans may already be in place to address accidental spills (from all sources) that threaten those resources. For example, the Old Woman Creek National Estuarine Research Reserve at Huron, Ohio, on Lake Erie, has developed a detailed spill response plan to address oil spills that could impact the estuary.

One factor that may greatly affect effective spill response is the remoteness of the well site or pipeline where the spill or leak is occurring. Remote locations may not be easily accessible, and responders may have difficulty in accessing the location. To address this issue,

some states have developed tools for reporting spills to help spill responders reach locations. For example, the State of Ohio has developed an Oil and Gas Well Emergency Response System that assists in online reporting of a release at permitted wells within the state, as well as providing location information of a well by map, well number, permit number, or latitude and longitude (available at http://199.218.11.215/). Such tools and programs will aid in reducing spill response times and in minimizing the duration and magnitude of a spill and its environmental effects.

Thus, the implementation of existing Federal, state, and site-specific programs, requirements, and tools should act to minimize the magnitude and extent of environmental effects from accidental oil spills that may occur at oil wells and pipelines.

6.2 POTENTIAL EFFECTS ON ECOLOGICAL RESOURCES

Ecological resources in the Great Lakes Basin may be affected during normal activities of all phases of oil and gas development. During normal operations, potential effects could be associated with seismic exploration; the drilling of E&P wells; the construction of the drill pads, pipelines, access roads, and utility corridors; and noise during operations. Biota and their habitats may also be affected by the accidental release or spill of oil or gas, as well as by the accidental release of drilling, production, and processing wastes. The magnitude of any adverse effects will depend on a number of factors, including the size and location of the oil and gas facility and on the magnitude and duration of any oil, gas, or waste product release that might occur. Both onshore and offshore wells have the potential to affect aquatic and terrestrial biota and habitats. Oil and gas development currently occurs throughout many of the Basin states, while oil and gas pipelines are present in all the states (Section 5.7). Regulations governing this existing production may be expected to apply to any new development of offshore reservoirs, thus mitigating many of the potential impacts identified in the following sections.

6.2.1 Coastal and Nearshore Habitats

The potential effects on coastal and nearshore habitats from slant drilling for oil and gas exploration, well construction, and production will be associated with:

- Direct impacts from ground-disturbing activities associated with well site construction;
- Direct and indirect effects of seismic exploration;
- Direct and indirect impacts from water quality degradation and altered hydrology associated with soil erosion, surface runoff, and water infiltration;
- The physical and chemical characteristics of petroleum and associated non-petroleum fluids;

- Direct and indirect effects of accidental releases of oil, gas, drilling wastes, and processing wastes; and

- Direct impacts from exposure to air emissions during extraction and processing activities.

Offshore oil and gas development may also affect coastal and nearshore habitats if accidental oil spills or waste releases are transported to shoreline areas and deposited into wetlands and other habitats by lake currents and waves. Impacts might also possibly result from ground disturbance associated with the landfall of pipelines originating at the offshore wellheads and from the construction of onshore storage and processing facilities.

6.2.1.1 Wetlands

Numerous wetlands occur along the coastlines and other nearshore areas of the Great Lakes (Section 5.2.2.1). Where oil and gas resources may be located in the northern Lower Peninsula of Michigan, along Lakes Michigan and Huron, coastal wetlands are especially abundant. Wetlands along the Lake Erie coastline are primarily located in the western portion of the lake, while oil and gas resources may be located in all portions of the lake. Onshore drilling sites would generally be located within 2.5 mi (4.02 km) of the shoreline. Impacts on wetlands from onshore development would be largely associated with the damage or loss of vegetation and habitat from seismic exploration, drilling, and construction activities. Offshore drilling to access oil and gas resources beneath the Great Lakes may impact coastal wetlands through the construction of offshore pipeline landfalls, onshore pipelines, storage and processing facilities, and access roads and utility corridors. Because regulations prohibit direct impacts to wetlands from exploration and construction, only indirect impacts would be expected to occur. Activities that would impact wetlands would require permits from the Corps and/or state agencies (see Section 4). The use of good engineering practices in the construction of well sites and facilities can greatly minimize impacts to wetlands. Table 6.1 summarizes the environmental effects that could occur from both onshore and offshore oil and gas development.

For both onshore and offshore sites, impacts from normal operation could be associated with maintenance activities or decreases in air or water quality. Wetlands could be affected during any of the phases of developing an oil or gas site by the accidental spill or release of oil or gas during exploratory drilling, well completion, and production, as well as by accidental releases of drilling, production, and processing wastes.

In addition to wetlands, other special aquatic sites also occur in nearshore areas of the Great Lakes (see Section 5.2.2.1). These sites could also be affected by oil and gas development in a manner similar to that of wetlands.

6.2.1.1.1 Exploration. Wetlands occur in all areas of oil and gas potential within the Great Lakes (Section 5.2.2.1). Although avoidance of wetlands during onshore exploration and drill site selection would generally be possible, direct impacts could potentially occur in some

TABLE 6.1 Potential Effects on Wetlands from the Development of Oil and Gas Resources Located beneath the Great Lakes

Development Phase	Nature and Cause	Duration and Extent
Onshore Development		
Exploration	Trampling of wetland vegetation and compaction of wetland substrates (e.g., sediments or soils) from vehicle and foot traffic during conduct of seismic evaluations.	Localized, may be long-term, limited to footprint of, and routes taken by, exploration teams and vehicles.
	Destruction of wetland vegetation during drilling of exploratory wells and logging.	Localized to drilling location. May be short-term if well is abandoned; long-term if well site is developed for production. Likely where long-term invasive vegetation becomes established.
Construction	Disturbance or loss of wetland vegetation and substrates from clearing and grading of well pad site and access road, pipeline, and utility corridor locations.	Long-term within facility and access road footprints, short-term and/or long-term within pipeline and utility corridors.
	Disturbance of adjacent wetland vegetation and function from altered surface and subsurface hydrology and increased sedimentation during site construction activities.	Long- and/or short-term, depending on types of wetlands adjacent to the well site and existing hydrologic regimes.
	Establishment of invasive, non-native vegetation (such as purple loosestrife) in areas disturbed by clearing and grading activities.	Long-term establishment of invasive vegetation, which could spread to adjacent wetland habitats.
	Fragmentation of wetland habitat due to siting of wellhead; storage and processing facilities; and pipeline, access road, and utility corridor.	Long-term. Extent dependent on quality and areal extent of wetlands that would be fragmented.
Operation	Disturbance from maintenance activities; reduced air quality and water quality near facilities; reduced water quality beyond facility if groundwater is affected.	Localized to facility location; generally intermittent and short-term; long-term and greater areal extent if groundwater is affected.
Accidental Spill or Release	Exposure of wetland vegetation and substrates to accidental releases of oil or gas, or of drilling, production, and processing wastes; potentially affecting vegetation survival, growth, or reproduction, and wetland quality and function, in immediate area of the release.	May be short-term, pending small spill size and rapid release containment and site cleanup. Potentially long-term depending on spill size, cleanup effectiveness, toxicity of released materials, and sensitivity of exposed wetlands biota. Duration and magnitude of effects would depend on toxicity of the released materials, the magnitude and duration of the release, and the condition and quality of affected habitats and biota.

TABLE 6.1 (Cont.)

Development Phase	Nature and Cause	Duration and Extent
Offshore Development		
Exploration	No effects expected.	No effects expected.
Construction	Disturbance or loss of wetland vegetation and substrates from onshore clearing and grading at pipeline landfall, storage and processing facilities, access road, utility corridors, and staging areas for pipeline construction.	Long-term within facility and access road footprints, short-term and/or long-term within pipeline and utility corridors.
	Disturbance of wetland vegetation and function from altered surface and subsurface hydrology and increased sedimentation during onshore construction activities.	Long- and/or short-term, depending on types of wetlands adjacent to the onshore locations and existing hydrologic regimes.
	Establishment of invasive, non-native vegetation in areas disturbed by clearing and grading activities.	Long-term establishment of invasive vegetation, which could spread to adjacent wetland habitats.
	Fragmentation of wetland habitat due to siting of wellhead; storage and processing facilities; and pipeline, access road, and utility corridor.	Long-term. Extent dependent on quality and areal extent of wetlands that would be fragmented.
Operation	Disturbance from maintenance activities; reduced air quality and water quality near facilities; reduced water quality beyond facility if groundwater is affected.	Localized to facility location; generally intermittent and short-term; long-term and greater areal extent if groundwater is affected.
Accidental Spill or Release	Exposure of shoreline wetland vegetation and substrates from accidental well or pipeline release, or of extraction and processing wastes; potentially affecting vegetation survival, growth, or reproduction, and the quality and function of exposed wetlands. Oil exposure of shoreline wetlands from offshore well blowout and subsequent coastline deposition.	Short-term, pending rapid release containment and site cleanup. Potentially long-term, depending on cleanup effectiveness. Duration and magnitude of effects would depend on toxicity of the released materials, the magnitude and duration of the release, and the condition and quality of affected habitats and biota.

areas. Impacts to wetlands (crushing of vegetation or substrate compaction) may occur as a result of the exploration teams and equipment conducting the seismic evaluations entering wetland areas during exploration. Survival of many native plant species and seedling establishment may be adversely affected. Soil compacting may also convert some vegetated wetland areas to open water or submerged vegetation communities. Such impacts could potentially result in long-term or major impacts on local wetlands, with effects in some cases lasting decades. Some wetland vegetation would also be disturbed or lost during installation of exploratory wells. It is very

likely that invasive plant species would colonize areas of disturbance, resulting in probable long-term effects.

6.2.1.1.2 Construction. For onshore wells, construction of a permanent drilling pad and associated structures (pipelines, access roads, and utility corridors) near the coastline may result in both temporary and permanent impacts on wetlands. Construction impacts may include:

- Permanent loss of vegetation and associated habitat from clearing and grading of the drill pad location;
- Permanent loss or disturbance of vegetation and habitat from clearing and grading of any required access roads, pipeline routes, utility corridors, and any associated construction support areas;
- Increased sedimentation in adjacent wetlands due to erosion and runoff from construction areas;
- Disturbance of local wetland vegetation and biota due to changes to surface and subsurface hydrology from altered surface runoff and infiltration patterns and rates;
- Disturbance of local wetland vegetation due to changes in groundwater hydrology from groundwater removal during drilling; and
- Habitat fragmentation due to siting of the drill pad, access roads, and pipeline and utility corridors.

Onshore drill sites may range from up to 5 or more acres (2 ha) in size, and site development would require the removal of vegetation and disturbance of soil and/or sediments from the drill site. Should the drill pad location necessitate that any pipelines, access roads, and/or utility corridors cross streams or other aquatic habitats (such as wetlands), additional removal of wetland vegetation, soils, and sediments would also occur, resulting in further loss of wetland habitat. These wetland losses (potentially long-term in nature) could result in the localized reduction or loss of wetland functions, such as fish and wildlife habitat, attenuation of flooding and shoreline erosion, and removal of substances that reduce water quality. Construction of drill sites, pipelines, roads, and utility corridors could also result in habitat fragmentation and separation of wetland areas, especially if construction took place in areas with existing roads and other facilities.

Indirect impacts on wetlands from the construction of onshore well sites may include altered hydrology from changes in surface drainage patterns or separation of surrounding wetland areas from adjacent water sources. Some wetlands, such as marshes and swamps (Section 5.2.2.1), are maintained in part by surface water flows, and the development of an oil or gas production site may result in both temporary and long-term changes to surface water inflow and/or outflow rates or patterns. Maintaining natural drainage patterns during site development

can minimize such effects. Soil compaction resulting from construction adjacent to wetlands may reduce the infiltration rates of precipitation into the soil and underlying groundwater, thereby increasing surface water runoff rates as well as the sediment load carried by the runoff. Increased surface water runoff from the well site and any access road and pipeline corridors may also increase the fluctuation of water surface elevations in adjacent wetlands (especially during precipitation events), resulting in greater extremes of high and low water levels, including reductions of the base flows and increases in flood flows of adjacent streams.

Fens and bogs (Section 5.2.2.1), which generally are not supported by surface flows, may be greatly affected by altered subsurface and surface hydrology. Water removal during drilling or the disposal of produced water may alter the subsurface hydrology on which the fens and bogs greatly depend. Hydrologic alteration of wetlands may result in an increase or decrease in the frequency, duration, depth, or extent of soil saturation or inundation, which is critical for many wetland plant species. Fens may also experience a reduction in groundwater inflow if a high degree of development (with its introduction of impervious surfaces) occurs within the recharge area. The establishment of buffer zones around wetlands, areas in which soil disturbance and use of heavy equipment is avoided, can minimize many indirect impacts to wetland hydrology.

Changes in surface and subsurface hydrology may result in the replacement of one wetland community type for another, or they may promote wetland losses by conversion to upland communities or conversion of wetland vegetation communities to open water. Soil compaction may also result in the loss of species richness and diversity. Many native wetland species indicative of high-quality habitats are sensitive to disturbance and may be displaced by species more tolerant of disturbance or by invasive non-native species, thereby reducing biodiversity. Invasive plant species typically develop high population densities and thereby exclude most other plant species, reducing native species abundance and diversity. Diversity in invertebrate, fish, and wildlife communities utilizing that habitat may also subsequently be reduced.

Degradation of water quality as a result of increased sedimentation from construction areas and/or groundwater disposal of produced water may also affect wetlands. Without proper site preparation, erosion of disturbed soils or insufficiently stabilized soils and unstable slopes following site grading may result in sediment inputs and turbidity in wetlands that receive storm water runoff. Runoff from exposed soil surfaces, such as the drill site, access roads, or pipeline rights-of-way (ROWs), may create turbidity in wetlands, increased temperature, and lower dissolved oxygen. Runoff from washdown areas may contain cuttings when air drilling is used. Erosion may occur at pipeline stream crossings. Sedimentation can alter plant communities, reducing plant density and biodiversity, decreasing sensitive species, and creating opportunities for invasive species establishment. The implementation of best management practices and good engineering practices, such as the use of silt fences for erosion and sedimentation control, would minimize such impacts to wetlands.

Offshore oil and gas wells will require onshore facilities, including pipelines, storage and processing facilities, access roads, and utility corridors. Impacts on wetlands from the construction of these onshore facilities would be similar to those identified for onshore oil and gas development. Wetland vegetation would be permanently disturbed within the facility

footprints, while potential alterations to surface and subsurface hydrology could affect wetlands in adjacent areas. Although offshore oil and gas development would not have an onshore well pad, the need for pipelines that transport the gas or oil from the wellhead on the lake bottom to an onshore processing and storage facility could affect more wetlands than would onshore oil and gas development. The construction of pipelines from offshore drilling rigs to onshore processing and storage facilities may also result in erosion of exposed soils and unstable slopes at pipeline landfalls, potentially affecting wetlands at those locations.

A number of Federal, state, and local regulations address the protection of wetlands. Refer to Section 4 for regulatory issues associated with these potential disturbances.

6.2.1.1.3 Operation. Access roads and utility corridor ROWs may allow for increased access and disturbance from recreational activities in previously undisturbed areas; the ROWs may also provide opportunities for invasive species to colonize these areas. Normal operations would include a variety of routine monitoring and maintenance activities that would not be expected to result in adverse environmental effects under normal circumstances. However, should concerns with a pipeline (e.g., unacceptable level of pipeline corrosion) or waste storage facilities (e.g., integrity concerns for on-site disposal pits for drilling muds) be identified during maintenance or monitoring, measures to address those concerns may include replacement or repair (such as the replacement of a section of buried pipeline), which could result in additional environmental impacts. In such an event, impacts would be similar in nature to those identified for construction, but would likely be of lesser magnitude because the resources would have previously been disturbed during facility construction.

Air quality near operating facilities may be reduced during normal operations. Exhaust emissions from equipment, atmospheric releases from wells or processing facilities, or fugitive dust generated from exposed soils could have local adverse effects on wetland vegetation. Storage or handling of waste products could introduce contaminants into wetlands, and contaminants could be present in storm water runoff that flows into wetlands. However, required pollution reduction measures would minimize air and water quality reductions near facilities, and these occurrences would generally be intermittent and infrequent. Subsequently, potential impacts to wetlands would be minimized.

Shallow groundwater may become degraded from disposal or injection of produced water and could potentially affect wetlands that receive groundwater discharge, such as fens, beyond the immediate facility location, vegetation and if biota are exposed to toxic contaminants. Subsequent effects may persist long-term. Injection is a widely accepted method for disposing of produced water (Section 2.3.2). However, local and state regulations would likely direct operational requirements for the protection of groundwater, and collection, rather than discharge, of fluids may be required.

6.2.1.1.4 Accidental Spills and Releases. Spills of oil or drilling and processing waste materials may occur during each of the phases of oil and gas development, and these may affect wetland communities. With slant drilling, there is little potential for oil to migrate from the

bottom hole (which would be located under the lake bottom) to overlying surface water, because the geologic units above the oil-bearing units will act to prevent such an upward movement of oil or gas. For example, in Lake Michigan, the Niagaran Reef reservoirs are overlain by thousands of feet of impermeable rock strata (MESB 1997). Because of these layers, oil or gas can only come to the surface through the well borehole. More likely is an accidental release at the wellhead because of a blowout. However, the use of blowout preventers (see Section 2.2.2) significantly reduces (but does not eliminate) the likelihood of such a release.

Uncontrolled onshore spills may cover vegetation and wetland soils and sediments (Figure 6.3) and may result in the elimination of wetland biota in affected areas, including aquatic invertebrates and vegetation. The severity of the effect will depend on the chemical and toxicological nature of the released materials and the duration and frequency of the release. Spills of some petroleum products, such as diesel fuel, can result in higher mortality and poorer recovery of vegetation than would result from crude oil spills.

FIGURE 6.3 Oiled Wetland Sediments and Vegetation (EPA 2005f)

Exposure to spills may result in a decrease in the abundance of wetland plants and animals. Onshore spills that enter streams may impact delta, estuarine, and riverine wetlands along Great Lakes tributaries. Spills that subsequently enter the lake may also affect coastal lagoon, solution basin, and fringing wetlands along the coastline.

Spills may also result in the loss of sensitive wetland plant species, which often occur in high-quality undisturbed wetlands, and affected areas may become populated only by more tolerant species. Disturbance of wetland communities very often leads to colonization by invasive plant species, many of which are non-native. Therefore, spills may also promote the establishment of invasive plant species that may compete with and potentially displace native wetland vegetation. This would result in a decrease in the quality of the wetland and affect its role in providing wildlife habitat. Although spills from a variety of sources may affect wetlands, spills at onshore well sites are typically contained by barriers constructed around the well site.

Offshore oil spills may occur at well sites or along lake-bottom pipelines. An offshore well may also experience an accidental release of production wastes. At a well site, an oil or gas release may occur as a result of inadequate well completion and casing, or from a well blowout (Figure 6.4), due to sudden, uncontrolled releases of fluids from a wellbore or wellhead resulting from improperly balanced well pressures. The use of blowout preventers reduces (but does not eliminate) the likelihood of such a release (Section 2.2.2). Surface water affected by a release of oil or drilling wastes may enter coastal wetlands that have hydrologic connections to the lake, especially estuarine, coastal lagoon, solution basin, and fringing wetlands, thus also affecting nearshore wetlands. Coastal wetlands are ranked most sensitive (10 on a scale of 1 to 10) in environmental sensitivity indices (ESIs) (NOAA 1985, 1994; Herdendorf 1987) Wetlands may also be affected by spills from onshore pipelines and storage and processing facilities. A large

number of pipelines currently exist within the Great Lakes Basin near the lake shores. Pipeline leaks occasionally occur (see Section 3), with risks to wetlands similar to those of newly constructed pipelines. Natural gas may also be released during the drilling or production of natural gas from offshore reservoirs; however, such gas leaks may be masked by the natural production and release of methane from nearshore wetland substrates.

Oil spills that are not cleaned up may persist in wetland soils and sediments for considerable periods of time, even decades, resulting in long-term impacts on wetland vegetation and biota (Herdendorf 1987; NOAA 1985). Spill cleanup may require the excavation and removal of contaminated soils, resulting in additional loss of wetland vegetation beyond that lost during site construction. Where oil spills occur in flooded areas or on saturated soils, recovery of vegetation is generally better than that on unsaturated soils (DOI 2002).

6.2.1.2 Other Nearshore Habitats and Vegetation

FIGURE 6.4 Extreme Example of Offshore Well Blowout (The IXTOC 1 exploratory well blew out on June 3, 1979, in the Bay of Campeche off Ciudad del Carmen, Mexico.) (Source: NOAA 2005b)

The potential effects on other nearshore habitats, such as beaches, dunes, sand barrens, and islands (see Section 5.2.3), from either onshore or offshore oil and gas development would be similar to those identified for wetlands. Potential effects from onshore well development would be largely associated with ground-disturbing activities (during exploration and construction) and accidental releases of oil and gas or of drilling, production, and processing wastes. The development of offshore wellheads may affect nearshore habitats in a similar manner, namely through (1) the accidental offshore release of oil and drilling wastes and their subsequent transport to nearshore habitats by lake currents and wave action; (2) the construction and operation of offshore pipeline landfalls and onshore pipelines, storage and processing facilities, and access roads and utility corridors; and (3) the accidental release of oil or processing wastes from onshore pipelines, storage facilities, and processing facilities. Table 6.2 summarizes the potential environmental effects from onshore and offshore development.

Nearshore habitats that have been identified as unique and/or of concern (see Section 5.2.3 for descriptions and distributions of these habitats) and that are present along the coastlines of Lakes Michigan, Huron, and Erie where oil and gas development may occur include:

- Sand beaches around northern Lake Michigan, especially along the northwestern coast of the lower peninsula of Michigan (Figure 5.12);

- Sand beaches along the coastlines of Lake Erie (Figure 5.12);

TABLE 6.2 Potential Effects on Other Nearshore Habitats and Vegetation from the Development of Oil and Gas Resources Located beneath the Great Lakes

Development Phase	Nature and Cause	Duration and Extent
Onshore Development		
Exploration	Trampling of vegetation and compaction of substrates (e.g., sand, gravel, cobble, and soil) from vehicle and foot traffic during conduct of seismic evaluations.	Localized, may be long-term; limited to footprint of, and routes taken by, exploration teams and vehicles.
	Destruction of vegetation and disturbance of substrates during drilling of exploratory wells and logging.	Localized and limited to drilling location. Short- or long-term, depending on type of vegetation affected and whether the well is abandoned. Long-term if well site is developed for production.
Construction	Disturbance or loss of vegetation and substrates from clearing and grading of well pad site and access road, pipeline, utility corridor locations, and construction staging areas.	Long-term within facility and access road footprints, short-term and/or long-term within pipeline and utility corridors.
	Disturbance of adjacent habitats and vegetation from altered surface and subsurface hydrology during site construction activities.	Long- and/or short-term, depending on types of habitats and vegetation adjacent to the well site and their sensitivity to altered hydrologic conditions.
	Establishment of invasive, non-native vegetation in areas disturbed by clearing and grading activities.	Long-term establishment of invasive vegetation, which could spread to adjacent habitats and compete with native vegetation.
	Fragmentation of habitats due to location of the wellhead; storage and processing facilities; and pipeline, access road, and utility corridor.	Long-term. Extent and magnitude dependent on quality and areal extent of the habitats that could be fragmented.
Operation	Disturbance from maintenance activities; reduced air quality near facilities; reduced water quality if groundwater is affected.	Localized to facility location; generally intermittent and short-term; long-term and greater areal extent if groundwater is affected.
Accidental Spill or Release	Exposure of adjacent habitats, vegetation, and substrates from accidental release of oil (due to well blowout) or of extraction and processing wastes, potentially affecting survival, growth, and reproduction of vegetation and habitat quality.	Short-term, pending rapid release containment and site cleanup. Potentially long-term, depending on cleanup effectiveness. Duration and magnitude of effects would depend on toxicity of the released materials, the magnitude and duration of the release, and the condition and quality of affected habitats and biota.

TABLE 6.2 (Cont.)

Development Phase	Nature and Cause	Duration and Extent
Offshore Development		
Exploration	No effects expected.	No effects expected.
Construction	Disturbance or loss of habitat, vegetation, and substrates from onshore clearing and grading at pipeline landfall, storage and processing facility, access road, utility corridor locations, and construction staging areas.	Long-term within facility and access road footprints, short-term and/or long-term within pipeline and utility corridors.
	Disturbance of habitats and vegetation from altered surface and subsurface hydrology and increased sedimentation associated with onshore construction activities.	Long- and/or short-term, depending on types of wetlands adjacent to the onshore locations and existing hydrologic regimes.
	Establishment of invasive, non-native vegetation in areas disturbed by clearing and grading activities.	Potential long-term establishment of invasive vegetation, which could spread to adjacent wetland habitats.
	Fragmentation of habitats due to siting of wellhead; storage and processing facilities; and pipeline, access road, and utility corridor.	Long-term. Extent dependent on quality and areal extent of wetlands that would be fragmented.
Operation	Disturbance from maintenance activities; reduced air quality near facilities; reduced water quality if groundwater is affected.	Localized to facility location; generally intermittent and short-term; long-term and greater areal extent if groundwater is affected.
Accidental Spill or Release	Exposure of vegetation and substrates to accidental onshore pipeline releases or onshore releases of production and processing wastes, potentially affecting survival, growth, and reproduction of vegetation and habitat quality. Exposure of coastline vegetation and habitats (such as sand beaches) from offshore well blowout and subsequent coastline deposition.	Short-term, pending rapid release containment and site cleanup. Potentially long-term, depending on cleanup effectiveness. Duration and magnitude of effects would depend on toxicity of the released materials, the magnitude and duration of the release, and the condition and quality of affected habitats and biota.

- Sand beaches along the western shore of Lake Huron and the lower peninsula of Michigan (Figure 5.12);
- Sand dunes along the northern coastline of the lower peninsula of Michigan, Lakes Michigan and Huron (Figure 5.13);
- Bedrock and cobble beaches on the western shore of Lake Huron, the lower peninsula of Michigan, and the coastline of Lake Erie (Figure 5.14);

- Lakeplain prairies along Saginaw Bay, Lake Huron (Figure 5.15);

- Sand barrens in the lower peninsula of Michigan, along the western coast of Lake Huron and the northern tip of Lake Michigan (Figure 5.16);

- Shoreline alvars along the northern shores of Lakes Michigan and Huron on the upper peninsula of Michigan, as well as in the western basin of Lake Erie (Figure 5.19); and

- Islands in northeastern Lake Michigan and western Lake Erie (Figure 5.20).

Arctic-alpine disjunct communities and Arctic coastal plain disjunct communities are extremely rare along U.S. Great Lakes shorelines. These communities are highly vulnerable to disturbance, but neither of them occurs in areas of oil and gas resources, and thus they would not be expected to be affected by oil and gas development.

For many unique nearshore habitats, their natural characteristics and environmental conditions make them very susceptible to disturbance and make restoration and recovery following any kind of disturbance very difficult. For example, vegetation in bedrock and cobble beaches is generally very limited because of wave and ice action, and revegetation of disturbed sites within these communities may be very difficult. Similarly, shoreline alvars occur on very thin soils over bedrock and normally experience flood and drought conditions. They are easily disturbed by ground surface activities, which may make restoration of disturbed areas very difficult.

6.2.1.2.1 Exploration. Impacts on nearshore habitats and vegetation would be similar to those identified for wetlands and other special aquatic sites (see Section 6.2.1.1). Impacts from onshore development may include trampling of vegetation and compaction of substrates by foot and vehicle traffic, loss of vegetation within the immediate drilling footprint, and accidental exposure of vegetation and substrates to oil and drilling wastes (Table 6.2). Seismic acquisition activities conducted in shallow water of the near-shore zone or in bays, lagoons, and quiet water areas near beach habitats may substantially impact near-shore habitats. Offshore exploration activities are not expected to affect nearshore habitats.

6.2.1.2.2 Construction. Impacts from onshore construction activities for onshore wells would be associated with clearing and grading operations for drill site preparation, pipeline ROWs, roadways, and utility corridors. These impacts would be similar to those identified for wetlands and special aquatic sites and include short- and long-term losses of vegetation and habitat, reduced habitat quality, and establishment of invasive vegetation. Other site work that could affect nearshore habitats may include excavation and the placement of fill materials to provide a stable subsurface for drilling pads, pipelines, or other structures, such as in areas of sandy soils. In addition to direct habitat losses, erosion of sand beaches and dunes may be induced because of storm water runoff, wind erosion, or sloughing of unstable slopes.

Stabilization of dune margins may be difficult, and establishment of vegetation cover may be slow, possibly resulting in prolonged losses of dune habitat near construction areas. Similar effects may be incurred for offshore well development, except that offshore construction of the wellhead and lake-bottom pipeline would not be expected to affect nearshore habitats.

6.2.1.2.3 Operation. Normal operations would include a variety of routine monitoring and maintenance activities that would not be expected to result in adverse environmental effects under normal circumstances. However, should concerns with a pipeline (e.g., unacceptable level of pipeline corrosion) or waste storage facilities (e.g., integrity concerns for on-site disposal pits for drilling muds) be identified during maintenance or monitoring, measures to address those concerns may include replacement or repair (such as the replacement of a section of buried pipeline), which could result in additional environmental impacts. In such an event, impacts would be similar in nature to those identified for construction, but they would likely be of lesser magnitude because the resources would have previously been disturbed during facility construction.

Air quality near constructed facilities may be reduced during normal operations. Exhaust emissions from equipment, atmospheric releases from wells or processing facilities, or fugitive dust generated from exposed soils could have local adverse effects on vegetation. However, required pollution reduction measures would minimize air quality reductions near facilities, and these occurrences would generally be intermittent and infrequent. Subsequently, potential impacts to nearshore habitats would be minimized.

Shallow groundwater may become degraded from disposal or injection of drilling muds, cuttings, or produced water and could potentially affect vegetation through root uptake of contaminants. Subsequent effects may persist long-term. However, local and state regulations would likely direct operational requirements for the protection of groundwater, and collection, rather than discharge, of fluids may be required.

6.2.1.2.4 Accidental Spills and Releases. Shoreline habitats would be affected by accidental oil spills from wellheads, storage tanks, or pipelines. Accidental releases of drilling wastes and processing wastes may also affect nearshore habitats. Oil and other released materials would quickly penetrate nearshore habitats with permeable substrates (such as sand beaches, sand dunes, and cobble beaches); even with cleanup, residual oil could remain below the surface for many years (Short et al. 2001, 2004; DOI 2003). Sand and cobble beaches are ranked as moderately sensitive in ESI ranking (sand beaches = 4, cobble beaches = 6 on a 1 to 10 scale, 10 being most sensitive), and bedrock shores are ranked low (ESI = 2) (Herdendorf 1987; NOAA 1985, 1994). Oil left on uncleaned cobble beaches may become asphalt-like. Although oil may penetrate cracks in bedrock shores, oil persistence is generally limited to days or weeks. Although oil may be largely removed from cobble beaches in highly exposed locations through wave and ice action, oil may remain in the shallow subsurface for extended periods of time, thus affecting the reestablishment or health (from bioaccumulation of toxic substances) of vegetation and other biota.

Because of their rarity and vulnerability to disturbance, some nearshore habitats such as alvars and dunes could be severely affected by accidental spills of oil, gas, and/or production and processing wastes. Oil or other toxic materials spilled onto ground surfaces may result in direct mortality of plants and animals, and migration through the soil may make recovery and restoration difficult. Nearshore habitats with highly permeable soils, such as sand beaches, dunes, and barrens, may experience rapid migration of contaminants through the root zone. Mortality of vegetation is generally greater, and recovery poorer, from oil spills on upland soils than on saturated or flooded soils (DOI 2002). Communities on surface or near-surface bedrock, such as bedrock beaches and alvars, would likely experience a wide surface coverage of spilled fluids, with potentially more extensive ground surface contamination and injury to biota than would occur on permeable soils.

Under certain conditions, accidental spills from an offshore wellhead and lake-bottom pipelines could reach nearshore habitats such as beaches and dunes, via currents and wave action. Shoreline currents of the Great Lakes generally flow in a counterclockwise direction around the lake perimeter (Hough 1958). Exceptions are a clockwise movement at the western tip of Lake Superior and most of the Wisconsin shoreline of Lake Michigan. Flow is generally to the east in most of Lake Ontario and in Lake Erie shorelines near the Detroit and Niagara Rivers. Onshore releases could directly affect nearshore habitats if present along the pipeline or adjacent to any storage or processing facilities. Exposed biota could suffer reduced reproduction, growth, or survival, while substrates could become contaminated with the released materials. The magnitude and extent of environmental effects from such exposure would depend on the volume and duration of the release, the toxicity of the materials released, the specific habitats and biota exposed to the release, and the speed and effectiveness of cleanup and restoration activities.

6.2.2 Offshore Habitats

Effects of oil and gas development on off-shore habitats, such as artificial reefs and shallow water areas used as spawning or nursery habitats, especially the fish spawning reefs of western Lake Erie, would be primarily associated with (1) the disturbance of lake-bottom habitats from well installation and lake-bottom pipeline construction, (2) the degradation of overlying water quality during off-shore drill platform and pipeline construction, and (3) from accidental spills and releases (Table 6.3). Onshore oil and gas development would not be expected to affect offshore habitats unless the release entered the lake and was transported to the offshore habitats. Such a scenario is highly unlikely; however, nearshore reefs and islands have a relatively higher risk.

6.2.2.1 Exploration

Exploration activities may affect offshore habitats by disturbing a relatively small amount of lake-bottom habitat during exploratory drilling and by the accidental release of oil and drilling wastes. Sediments disturbed during exploratory drilling may be expected to quickly resettle, with little lasting effect on overlying water quality or habitat quality at the drill location. Drill cuttings may be washed and discharged into the lake, as is currently practiced in Canadian waters of

Lake Erie. Cutting discharges typically cover a bottom area with a 250-ft (76-m) radius and meet chemical criteria for lakefill material set by the Province of Ontario. Drilling muds are collected for reuse.

TABLE 6.3 Potential Effects on Offshore Habitats from the Development of Oil and Gas Resources Located beneath the Great Lakes

Development Phase	Nature and Cause	Duration and Extent
Onshore Development	No effects expected.	No effects expected.
Offshore Development		
Exploration	Disturbance of lake-bottom habitats during installation of a drilling rig and/or drilling template.	Very localized and short-term if the well is abandoned.
	Reduced water quality because of increase in suspended sediments potentially affecting nearby biota.	Very localized, limited to drilling location, and short-term.
Construction	Disturbance or loss of bottom habitat from the permanent installation of the drilling template and possibly the drilling platform, and from the construction of a pipeline from the well location to an onshore storage and processing facility.	Long-term habitat loss within drilling template and pipeline footprints. Additional long-term habitat loss if jack-up or submersible rigs (Section 2.2.2) are employed.
	Reduced water quality because of increase in suspended sediments in the lake water overlying the wellhead and pipeline locations, potentially affecting biota in surrounding habitats.	Short-term. Extent and magnitude of potential effects would depend on the existing water quality in these areas and on the biota that use the habitats in these areas.
Operation	No effects expected. Potential exposure to directly discharged production water; potentially affecting growth, survival, or reproduction of exposed biota.	No effects expected. Effects associated with production water discharge would be very localized and likely minor.
Accidental Spills or Releases	Exposure of adjacent habitats, sediments, and biota to accidental release of oil because of well blowout or pipeline failure, or the release of extraction and processing wastes; potentially affecting the distribution, survival, growth, and reproduction of biota and habitat quality in surrounding areas.	Short-term pending rapid release containment and site cleanup. Potentially long-term, depending on cleanup effectiveness. Duration and magnitude of effects would depend on toxicity of the released materials, the magnitude and duration of the release, and the condition and quality of affected habitats and biota.

6.2.2.2 Construction

Sediments could be disturbed during (1) the construction and anchoring of offshore drilling platforms (jack-up and submersible rigs; see Section 2.2.2), (2) installation of drilling templates and wellheads, and (3) installation of lake-bottom pipelines. This disturbance could increase turbidity and decrease water quality in the vicinity of the construction activity. The suspended sediments may not only affect the habitats at the well location, but may also be transported by lake currents to nearby off-shore habitats. Resulting siltation in these habitats could adversely affect invertebrate populations or the productivity of aquatic vegetation; however, some suspension of bottom sediments generally occurs under natural conditions such as storm events. Fish species that are dependent on these habitats may subsequently be affected, temporarily fleeing the construction area. Because construction would be relatively short term, potential impacts associated with increased turbidity and siltation would not be expected to last beyond the construction period. If the disturbed bottom sediments are also contaminated (see Section 5.6), local biota may be further affected by exposure to the contaminated sediments.

The construction of pipelines in shallow-water habitats may result in the localized elimination of small areas of habitat and an associated loss of biota (invertebrates and aquatic vegetation). For each mile of unburied pipeline constructed in the nearshore zone, approximately 1 acre (2 ha) of shallow-water habitat may be disturbed (USACE 1982). This loss of habitat would remain for the life of the facilities. However, benthic communities recover to pre-construction levels in approximately 1 year following the construction of buried pipelines.

Drilling wastes produced during well completion may adversely affect offshore habitats. Water-based muds and cuttings may contain constituents (see Section 2.3.1) or have pH levels that could affect biota if released into waters at the drill site.

6.2.2.3 Operation

During operations, offshore habitats may be affected by the release of produced water. Depending on applicable regulatory requirements, produced water may be directly discharged to the lake or may be accidentally released following injection into a disposal well (see Section 2.3.2). Exposure to these wastes may affect biota in the immediate vicinity of the production site. These constituents may also be carried by lake currents from the well location to other offshore habitats and adversely affect biota at those locations.

6.2.2.4 Accidental Spills and Releases

Releases of drilling wastes during exploratory and production well drilling, as well as accidental oil releases from wellheads and pipelines, may not only affect surrounding offshore habitats, but also be transported by lake currents to more distant offshore habitats. Oil that is not readily cleaned up may form deposits on bottom sediments, thus affecting the survival, growth, and reproduction of some bottom-dwelling fauna and aquatic vegetation. Oil that is not

subsequently removed may remain on or in the bottom sediments for extended periods of time, resulting in chronic exposure of some biota.

The magnitude and extent of environmental effects from such exposure would depend on the volume and duration of the release, the toxicity of the materials released, the specific habitats and biota exposed to the release, and the speed and effectiveness of cleanup and restoration activities.

6.2.3 Inland Habitats and Vegetation

Potential effects of oil and gas E&P on inland terrestrial habitats would be similar to those described for wetlands and nearshore habitats (Section 6.2.1). These effects would be primarily associated with ground disturbance, changes in groundwater and surface water quality and flow, habitat fragmentation, accidental oil and gas releases, and accidental releases of drilling and processing wastes (Table 6.4). Offshore development would similarly affect inland habitats or vegetation along onshore pipelines, processing and storage facilities, access roads, utility corridors, and platform or pipeline construction staging areas.

Many of the terrestrial habitats occurring in the oil- and gas-producing area of northern Lakes Michigan and Huron support coniferous and deciduous forests, with timber management and agriculture being common land uses. Grasslands are present, mostly on the Wisconsin side of Lake Michigan. The oil and gas production areas of Lake Erie contain extensive areas of agriculture, as well as urban and industrialized areas, with beech-maple woodlots. These communities have generally been greatly affected by human activities since European settlement, and undisturbed habitats are primarily small and relatively rare. Generally, the current habitat types are common in much of the Great Lakes Basin. Ecological impacts to terrestrial habitats may be less in agricultural or industrial areas if activities occur on disturbed agricultural or industrial land.

Staging areas for pipeline construction and fabrication yards for large offshore platforms may disturb large areas of inland habitat. While direct impacts (vegetation loss and soil disturbance) would occur during the construction period, habitat recovery may require extended periods beyond the completion of all construction activities.

6.2.3.1 Exploration

Impacts on inland habitats and vegetation during exploration would be similar to those identified for wetlands and nearshore habitats. Impacts would be associated with the trampling of vegetation and soils by foot and vehicle traffic, disturbance of vegetation and soils during drilling, and the accidental release of oil and gas and drilling wastes (Table 6.4). In addition, air drilling (instead of using muds) can generate dusts that may affect nearby biota. Runoff from washdown areas may contain cuttings.

TABLE 6.4 Potential Effects on Inland Vegetation and Habitats from the Development of Oil and Gas Resources Located beneath the Great Lakes

Development Phase	Nature and Cause	Duration and Extent
Onshore Development		
Exploration	Trampling of vegetation and soils from vehicle and foot traffic during conduct of seismic evaluations.	Localized, may be long-term; limited to footprint of, and routes taken by, exploration teams and vehicles.
	Destruction of vegetation and disturbance of soils during drilling of exploratory wells and logging.	Localized and limited to drilling location. Short- or long-term, depending on type of vegetation affected and whether well is abandoned. Long-term if well site is developed for production.
Construction	Disturbance or loss of vegetation and soils from clearing and grading of well pad site, access road, pipeline, utility corridor locations, waste disposal facilities, and construction staging areas.	Long-term within facility and access road footprints, short-term and/or long-term within pipeline and utility corridors.
	Disturbance of vegetation in adjacent habitats from altered surface and subsurface hydrology during site construction activities.	Long- and/or short-term, depending on types of habitats and vegetation adjacent to the well site and their sensitivity to altered hydrologic conditions.
	Establishment of invasive, non-native vegetation in areas disturbed by clearing and grading activities.	Long-term establishment of invasive vegetation, which could spread to adjacent habitats and compete with native vegetation.
	Fragmentation of habitats because of the location of the wellhead; storage and processing facilities; and pipeline, access road, and utility corridor.	Long-term. Extent and magnitude dependent on quality and areal extent of the habitats that could be fragmented.
Operation	Potential disturbance from maintenance and monitoring activities; reduced air quality near facilities; reduced water quality if groundwater is affected.	Localized to facility location; generally intermittent and short-term; long-term and greater areal extent if groundwater is affected.
Accidental Spill or Release	Exposure of habitats, biota, and soils from accidental release of oil (due to well blowout) or of drilling and processing wastes; potentially affecting survival, growth, and reproduction of biota and reducing habitat quality.	Short-term, pending rapid release containment and site cleanup. Potentially long-term, depending on cleanup effectiveness. Duration and magnitude of effects would depend on toxicity of the released materials, the magnitude and duration of the release, and the condition and quality of affected habitats and biota.

TABLE 6.4 (Cont.)

Development Phase	Nature and Cause	Duration and Extent
Offshore Development		
Exploration	No effects expected.	No effects expected.
Construction	Disturbance or loss of habitat, vegetation and substrates from onshore clearing and grading at pipeline landfall, storage and processing facilities, access roads, utility corridor locations, and construction staging areas.	Long-term within facility and access road footprints, short-term and/or long-term within pipeline and utility corridors.
	Disturbance of habitats and vegetation from altered surface and subsurface hydrology and increased sedimentation associated with onshore construction activities.	Long- and/or short-term, depending on types of wetlands adjacent to the onshore locations and existing hydrologic regimes.
	Establishment of invasive, non-native vegetation in areas disturbed by clearing and grading activities.	Potential long-term establishment of invasive vegetation, which could spread to adjacent wetland habitats.
	Fragmentation of habitats because of siting of wellhead; storage and processing facilities; and pipeline, access road, and utility corridor.	Long-term. Extent dependent on quality and areal extent of wetlands that would be fragmented.
Operation	Potential disturbance from maintenance and monitoring activities of onshore facilities; reduced air quality near facilities; reduced water quality if groundwater is affected.	Localized to facility location; generally intermittent and short-term; long-term and greater areal extent if groundwater is affected.
Accidental Spill or Releases	Exposure of habitats, biota, and soils associated with onshore facilities (such as pipelines) from accidental release of oil or of production and processing wastes; potentially affecting survival, growth, and reproduction of biota and reducing habitat quality.	Short-term, pending rapid release containment and site cleanup. Potentially long-term, depending on cleanup effectiveness. Duration and magnitude of effects would depend on toxicity of the released materials, the magnitude and duration of the release, and the condition and quality of affected habitats and biota.

6.2.3.2 Construction

Construction of drill pads, pipelines, access roads, drilling and processing waste facilities, and utility corridors would result in losses of habitat because of clearing and grading of the well site and associated facility locations (Table 6.4). Construction would result in the loss or disturbance of habitat and vegetation within the immediate footprint of the well pad, pipeline, storage and processing facilities, and utility corridors; this effect would be long term. Staging areas for pipeline construction and fabrication yards for large offshore platforms may disturb large areas

of inland habitat. Although direct impacts (vegetation loss and soil disturbance) would occur during construction, habitat recovery following construction may require extended periods. Shallow groundwater may become degraded during disposal; injection of drilling muds, produced water, or cuttings could potentially affect vegetation through root uptake. Local and state regulations would likely direct operations requirements for the protection of groundwater, and collection, rather than discharge, of drilling muds may be required.

Vegetation in the vicinity of the drill site may also be affected during construction by fugitive dust generated from exposed soils during clearing, grading, and construction activities, and from unpaved access roads. The deposition of fugitive dust on vegetation may result in reduced photosynthesis and primary production in adjacent habitats. However, such impacts would likely be minor and of short duration.

Depending on the siting of the drill rig and any associated access roads, pipelines, and utility corridors, the development of an oil or gas well site may result in the fragmentation of the habitat where the well site is located. The consequences of any such fragmentation would depend on the nature of the habitat being affected, including its size and occurrence in the area of the well site development.

6.2.3.3 Operation

During normal operation, erosion may be induced adjacent to pipelines at landfalls as a result of the effect of ice and storms. Losses of soil and vegetation may be considerable. Normal operations would include a variety of routine monitoring and maintenance activities that would not be expected to result in adverse environmental effects under normal circumstances. However, should concerns with a pipeline (e.g., unacceptable level of pipeline corrosion) or waste storage facilities (e.g., integrity concerns for on-site disposal pits for drilling muds) be identified during maintenance or monitoring, measures to address those concerns may include replacement or repair (such as the replacement of a section of buried pipeline), which could result in additional environmental impacts. In such an event, impacts would be similar in nature to those identified for construction, but they would likely be of lesser magnitude because the resources would have previously been disturbed during facility construction.

Air quality near constructed facilities may be reduced during normal operations. Exhaust emissions from equipment, atmospheric releases from wells or processing facilities, or fugitive dust generated from exposed soils could have local adverse effects on vegetation. However, required pollution reduction measures would minimize air quality reductions near facilities, and these occurrences would generally be intermittent and infrequent. Subsequently, potential impacts to inland habitats would be minimized.

Shallow groundwater may become degraded from disposal or injection of drilling muds, cuttings, or produced water and could potentially affect vegetation through root uptake of contaminants. Subsequent effects may persist long-term. However, local and state regulations would likely direct operational requirements for the protection of groundwater, and collection, rather than discharge, of fluids may be required.

6.2.3.4 Accidental Spills and Releases

Accidental releases of oil and gas from the wellhead or pipelines, or of processing wastes, could result in direct exposure of terrestrial biota, potentially affecting growth, survival, and reproduction of exposed biota and reducing habitat quality. Following a release, some contaminants would move into the soil and potentially migrate to shallow groundwater, subsequently entering the root zone of and affecting nearby vegetation. The magnitude and extent of environmental effects from such exposure would depend on the volume and duration of the release, the toxicity of the materials released, the specific habitats and biota exposed to the release, and the speed and effectiveness of cleanup and restoration activities.

6.2.4 Fish

Fish may be affected during all phases of oil and gas development (Table 6.5). For onshore development, fish may be affected by the accidental release of oil or gas from a well head or pipeline, by the accidental release of drilling and processing wastes, and by degraded water quality and habitats due to erosion and runoff from construction areas. The effects on fish from offshore development would be similar, except that the likelihood for, and magnitude of, impacts on fish and their habitats may be greater, and more habitat disturbance may occur as a result of offshore pipeline construction. As previously discussed, it is unlikely that a release into overlying surface waters from the bottom hole of an onshore directionally drilled well would occur (see Section 6.2.1.1.4).

Potential effects from onshore wells would be largely limited to fish and their habitats present in surface waters that receive surface water runoff (and, to a lesser extent groundwater discharge) from the well site and its associated facilities or that are crossed by pipelines, access roads, and utility corridors. Offshore wells have a potential for affecting a greater number of fish and their habitats, because of the presence of an offshore well and a lake-bottom pipeline and also of an onshore pipeline and storage and processing facilities. Thus, offshore wells will likely be associated with more surface water habitat than would an onshore well. The greatest impacts would be associated with spills or releases that affect spawning habitats and nursery areas, which could result in population-level effects for some species. Effects may include reduced habitat quality and availability, reduced reproductive success, and reduced growth and survival. Depending on the species affected and the nature and magnitude of any effects, population-level effects could be experienced by some species.

6.2.4.1 Exploration

Exploration for onshore development could affect fish through the temporary disturbance of aquatic habitats by exploration vehicles crossing small streams (Table 6.5). During offshore exploration, fish could be affected by sound levels generated during seismic surveys, by the turbidity that would be generated during installation of the drilling template, and by the accidental release of oil and drilling wastes (Table 6.5). Potential effects would likely be short-term, localized, and relatively minor. Fish affected by the seismic surveys or increased turbidity

TABLE 6.5 Potential Effects on Fish from the Development of Oil and Gas Resources Located beneath the Great Lakes

Development Phase	Nature and Cause	Duration and Extent
Onshore Development		
Exploration	Avoidance of habitats because of reduced water quality associated with increased turbidity and disruption of aquatic habitats in streams crossed by exploration vehicles and equipment. May affect reproduction if spawning habitats affected.	Largely short-term and localized, limited to the immediate area of actual stream crossings. Long-term if spawning affected.
Construction	Increased turbidity and sedimentation because of erosion and runoff from construction areas, affecting habitat quality and potentially impacting reproduction by covering nests and eggs with silt.	Short-term in aquatic habitats receiving runoff from construction areas; duration largely limited to period of construction. Potential local population level effects, depending on season and fish spawning characteristics.
	Reduced habitat availability because of altered surface and subsurface hydrology during site construction activities, potentially affecting spawning and feeding.	Long- and/or short-term, depending on the duration of the altered hydrologic conditions. Potential local population-level effects.
	Habitat disturbance or loss in streams requiring pipeline and/or access road crossing.	Localized, short-or long-term depending on crossing requirements and design (e.g., culvert or pipeline burial). Potential effect on fish spawning movements in streams.
	Establishment of invasive, non-native vegetation in aquatic habitats disturbed by stream crossings.	Long-term establishment of invasive vegetation, which could affect fish habitat quality and spread to adjacent aquatic habitats, potentially resulting in local population-level effects.
Operation	Potential disturbance of normal behaviors of fish in nearby habitats during monitoring and maintenance activities.	Short-term; disturbed individuals likely to habituate to normal operations, while monitoring and maintenance activities expected to be short-term, not continuous.
Accidental Spill or Release	Exposure of adjacent habitats, biota, and sediments to accidental release of oil (because of well blowout) or of drilling and processing wastes; potentially impacting survival, growth, and reproduction of biota and reducing habitat quality.	Short-term exposure pending rapid release containment and effective site cleanup. Potential long-term effects, depending on cleanup effectiveness. Duration and magnitude of effects would depend on toxicity of the released materials, the species and life stage exposed, the magnitude and duration of the release, and the condition and quality of affected habitats and biota. Potential local population-level effects.

TABLE 6.5 (Cont.)

Development Phase	Nature and Cause	Duration and Extent
Offshore Development		
Exploration	Avoidance of seismic survey and exploratory drill locations.	Very localized and short-term if the well is abandoned. Fish expected to return following completion of seismic surveys and exploratory drilling.
	Reduced water quality because of increase in suspended sediments during drilling of exploratory wells; potentially affecting the distribution, survival, growth, and reproduction of exposed biota.	Very localized and short-term, limited to drilling location.
Construction	Loss of bottom habitat from the installation of the drilling template, blowout preventer, and possibly the drilling platform (Section 2.2.2), and from the construction of a pipeline from the well location to an onshore storage and processing facility.	Long-term habitat loss within drilling template and pipeline footprints. Additional long-term habitat loss if jack-up or submersible rigs (Section 2.2.2) are employed.
	Reduced quality because of increase in suspended sediments (increased turbidity) in the lake water overlying the wellhead and pipeline locations; potentially affecting survival, growth, and reproduction of biota in surrounding habitats.	Short-term or long term. Extent and magnitude of potential effects would depend on the existing water quality in these areas and the species that use the habitats in these areas, and whether the construction activity occurs in active spawning or nursery habitats.
	Increase in habitat associated with presence of new submerged structures could increase local abundance of some fish.	Long-term until subsurface structures removed.
Operation	No effects expected. Potential exposure to directly discharged production water; potentially affected growth, survival, or reproduction of exposed biota.	Minor and localized effects associated with production water discharger.
Accidental Spill or Release	Exposure of habitats, biota, and sediments to accidental release of oil (because of well blowout) or of drilling and processing wastes; potentially affecting survival, growth, and reproduction of fish and their food, and reducing habitat quality.	Short-term, pending rapid release containment and site cleanup. Potential long-term effects, depending on cleanup effectiveness. Duration and magnitude of effects would depend on toxicity of the released materials, the species and life stage exposed, the magnitude and duration of the release, and the condition and quality of affected habitats and biota. Potential population-level effects.

would likely leave the area, while fish exposed to an accidental release could incur a variety of lethal or sublethal effects. If spawning activities and reproduction are affected, local population levels may be impacted.

6.2.4.2 Construction

Effects from the construction of onshore and associated facilities would be similar to those identified for exploration, except that they could be of longer duration and potentially of greater magnitude (Table 6.5). Fish habitats could be affected by erosion and runoff from construction areas, as well as by changes in the surface and subsurface hydrology of the area where the well and associated facilities are being constructed. Effects from erosion and runoff may include a degraded habitat quality from the increased turbidity and sedimentation, as well as avoidance of the affected habitats, and affected fish would likely leave the disturbed habitats. These effects could be short or long term, depending on the nature of the receiving water body (e.g., small or large size, flowing or still water) but would largely cease following completion of construction activities. In addition, the likelihood and magnitude of adverse effects would be mitigated with careful site design and implementation of good engineering practices. Habitat disturbance because of altered hydrologic regime would be long term.

Construction of offshore wells and pipelines could result in the loss of benthic (lake bottom) fish habitat within the footprint of the drilling template, drill rig (if in contact with the lake bottom), and lake-bottom pipelines. Increases in turbidity during construction of these facilities may result in the temporary avoidance of nearby habitats by fish and in a temporary reduction in local habitat quality. Local population-level effects may be incurred if the affected habitats are active spawning or nursery habitats. Alternately, submerged structures could act as artificial reefs and increase habitat availability and attractiveness for some fish species.

6.2.4.3 Operation

Fish and their habitats are not expected to be affected by normal operations of either onshore or offshore wells and associated facilities (Table 6.5). Depending on applicable regulatory requirements, produced water from offshore wells may be directly discharged to the lake (see Section 2.3.2). Exposure to these wastes may affect the abundance, survival, or reproduction of biota in the immediate vicinity of the production site. These constituents may also be carried by lake currents from the well location to other offshore habitats and adversely affect biota at those locations. The presence of submerged wellheads in offshore areas may provide additional habitat for some species (similar to artificial reefs). Normal operations would include a variety of routine monitoring and maintenance activities that would not be expected to result in adverse environmental effects under normal circumstances. However, should concerns with a pipeline (e.g., unacceptable level of pipeline corrosion) or waste storage facilities (e.g., integrity concerns for on-site disposal pits for drilling muds) be identified during maintenance or monitoring, measures to address those concerns may include replacement or repair (such as the replacement of a section of buried pipeline), which could result in additional environmental impacts. In such an event, impacts would be similar in nature to those identified

for construction (related to the loss of bottom habitat, increased turbidity, and sediment resuspension), but they would likely be of lesser magnitude because the resources would have previously been disturbed during facility construction.

6.2.4.4 Accidental Spills and Releases

Accidental releases of oil, drilling and production wastes, and processing wastes may expose fish to contaminants that could adversely affect growth, reproduction, and survival. Accidental releases may also result in the deposition of oil or oil residues in spawning and nesting habitats, as well as habitats utilized by juvenile and adult fish for feeding; such releases may affect fish and their habitats not only in the vicinity of the release but also in other areas where currents may transport the released materials. Oil that is not readily cleaned up may form deposits on bottom sediments, thus affecting the survival, growth, and reproduction of bottom-dwelling fauna and aquatic vegetation, and thus, the habitat quality for some fish.

Exposure to the released materials may result in acute or chronic toxic effects, reducing survival, growth, and reproduction. Local or regional population-level effects may result if the release affects eggs or young fish, or reduces spawning and nursery habitat quality. Oil that is not subsequently removed may remain on or in the bottom sediments for extended periods of time, resulting in chronic exposure of some biota. Depending on the magnitude of the release, the speed with which the release is contained, the effectiveness of the cleanup, the location of the release or spill, and the species and life stage (egg, larvae, or adult) of the exposed fish, exposure to an accidental spill or release could result in local or regional population-level effects. Currently, all states have programs and requirements for addressing hazardous material releases. These would be implemented in the event of an accidental release, thus reducing the likelihood for and magnitude of impacts to fish.

6.2.5 Wildlife

Wildlife may be affected by a variety of factors related to oil and gas development. Wildlife may be disturbed by human presence and noise associated with exploration and construction activities; loss of habitat from clearing and grading activities; loss of less mobile wildlife (such as some amphibians and reptiles) in construction areas; noise and human activity during operations; and exposure to accidental releases of oil, gas, drilling and production wastes, and processing wastes (Table 6.6). Onshore activities may affect amphibians, reptiles, birds, and mammals, while effects at offshore locations would be largely limited to aquatic birds (waterfowl, gulls, and terns).

6.2.5.1 Exploration

Impacts associated with either onshore or offshore seismic surveys, would be largely limited to disturbance of biota by the presence and activity of the exploration teams and their equipment. Most biota would be expected to either temporarily leave the immediate exploration

area, or seek shelter in burrows and nests until the disturbance was over. Seismic disturbance on wildlife would be short-term, localized, and minor.

TABLE 6.6 Potential Effects on Wildlife from the Development of Oil and Gas Resources Located beneath the Great Lakes

Development Phase	Nature and Cause	Duration and Extent
Onshore Development		
Exploration	Disturbance of wildlife and their habitats from vehicle and foot traffic during conduct of seismic evaluations.	Short-term, limited to footprint of, and routes taken by, exploration teams and vehicles.
	Destruction of wildlife habitat during drilling of exploratory wells and logging.	Short-term if well is abandoned. Long term if well site is developed for production.
	Disturbance of wildlife because of increased noise and human presence. Disturbed wildlife may abandon or avoid exploration areas. Disturbance of colonial-nesting birds may affect reproductive success.	Short-term unless site is selected for full development. May be long term if disturbance affects reproductive success.
Construction	Disturbance or loss of habitat from clearing and grading of well pad site and access road, pipeline, and utility corridor locations.	Long-term within facility and access road footprints, short-term and/or long-term within pipeline and utility corridors.
	Disturbance of adjacent habitats from altered surface and subsurface hydrology during site construction activities.	Long- and/or short-term, depending on types of habitats disturbed and the wildlife that utilize those habitats.
	Avoidance or abandonment of adjacent habitats because of construction noise and activity. Disturbance of colonial-nesting birds could result in population level effects.	Short-term until construction activities completed. Long-term if reproduction affected.
	Establishment of invasive, non-native vegetation in areas disturbed by clearing and grading activities, reducing quality of wildlife habitat.	Long-term if invasive vegetation becomes established and spreads to adjacent habitats.
	Fragmentation of wildlife habitat from siting of wellhead; storage and processing facilities; and pipeline, access road, and utility corridor.	Long-term. Extent dependent on quality and areal extent of habitats that would be fragmented.
Operation	Disturbance of wildlife in adjacent habitats due to noise and human activity. Disturbance of colonial nesting birds could result in abandonment of nesting habitat and affect reproduction success, resulting in population level effects.	Short-term for species that may habituate to operational activities. Long-term for other species.

TABLE 6.6 (Cont.)

Development Phase	Nature and Cause	Duration and Extent
Accidental Spill or Release	Exposure of wildlife and adjacent habitats to accidental release of oil or of extraction and processing wastes. Survival, growth, and reproduction of exposed wildlife, as well as habitat quality, may be reduced, affecting local or regional wildlife populations.	Short-term, pending rapid release containment and site cleanup. Potential long-term effects depending on cleanup effectiveness. Duration and magnitude of effects would depend on toxicity of the released materials, the species and life stage exposed, the magnitude and duration of the release, and the condition and quality of affected habitats and biota. Potential local population-level effects.
Offshore Development		
Exploration	Exploration near shore-nesting birds may disturb adults and affect reproductive success. No other effects expected.	Potential long-term effects if reproductive success affected. No other effects expected.
Construction	Disturbance or loss of wildlife habitat from onshore clearing and grading at pipeline landfall, storage and processing facility, access road, and utility corridor locations.	Long-term within facility and access road footprints, short-term and/or long-term within pipeline and utility corridors.
	Disturbance of onshore wildlife habitat from altered surface and subsurface hydrology and increased sedimentation during onshore construction activities.	Long- and/or short-term, depending on types of habitats affected.
	Abandonment or avoidance of adjacent habitats because of construction noise and activity. Disturbance of colonial nesting birds could affect reproduction success and result in population level effects.	Short-term until construction activities completed. Long-term if reproduction affected.
	Establishment of invasive, non-native vegetation in onshore areas disturbed by clearing and grading activities, reducing the quality of wildlife habitat at the site and surrounding areas.	Long-term with establishment of invasive vegetation.
	Fragmentation of wildlife habitat from siting of wellhead; storage and processing facilities; and pipeline, access road, and utility corridors.	Long-term. Extent dependent on quality and areal extent of habitats that would be fragmented.
Operation	Disturbance of waterfowl and other aquatic birds by noise and human activities on well platforms. Disturbed biota may avoid operating platforms.	Short-term for species that readily habituate to noise and human activities. Long-term for sensitive species.

TABLE 6.6 (Cont.)

Development Phase	Nature and Cause	Duration and Extent
Operation	Offshore platforms (extending above the water surface) could provide resting locations for birds migrating across open waters of some lakes (especially Lake Erie), potentially increasing crossing-success for some birds.	Long-term until platform is removed.
Accidental Spill or Release	Exposure of wildlife and habitats from accidental onshore pipeline release or of extraction and processing wastes, affecting the quality of adjacent habitats. Exposure of coastline habitats and wildlife using shoreline and offshore habitats (i.e., diving birds and waterfowl) from offshore well blowout and subsequent coastline deposition. Ingestion of contaminated media or food may affect growth, survival, or reproduction.	Short-term, pending rapid release containment and site cleanup. Potential long-term effects, depending on cleanup effectiveness. Duration and magnitude of effects would depend on toxicity of the released materials, the species and life stage exposed, the magnitude and duration of the release, and the condition and quality of affected habitats and biota. Potential local population-level effects.

Construction of exploration wells could result in longer periods of disturbance, especially if the exploration well is developed. Should potentially sensitive biota, such as colonial-nesting birds, be disturbed, some population-level effects may be incurred.

6.2.5.2 Construction

Construction of onshore wells and associated facilities, and of the onshore portions of offshore wells, may affect wildlife in a similar manner. Effects would be associated with habitat loss at construction areas, loss of less mobile wildlife within the construction areas, avoidance of nearby habitats because of construction noise and activity, disturbance of adjacent habitats from altered surface and subsurface hydrology, reduction of habitat quality because of the establishment of non-native vegetation, and fragmentation of some habitats because of siting of pipelines, access roads, and utility corridors.

Habitat loss would be long-term within facility footprints. Reduced habitat quality because of altered hydrologic regimes would be long-term, but likely of limited extent. The disturbance of local biota by construction noise and activity would be short term and localized and would largely cease upon completion of the construction. However, construction noise and activities may result in the abandonment of nest areas or the disruption of normal nesting behaviors, which in the case of colonial nesting birds such as gulls, cormorants, and some herons, could result in some local population-level effects.

6.2.5.3 Operation

Under normal operations, nearby wildlife may be disturbed by noise and human activities associated with the site. Disturbed wildlife may abandon the area, while others may avoid the site. Some species may become habituated and return to normal behaviors, while others may leave the area for the duration of operations. If sensitive species or groups, such as colonial-nesting birds (gulls or cormorants), are disturbed, reproductive success may be affected. If offshore platforms that extend above the lake surface are employed, these platforms may providing rest areas for birds migrating across the open waters of the Great Lakes.

Normal operations would include a variety of routine monitoring and maintenance activities, and these are not expected to result in adverse environmental effects under normal circumstances. Wildlife could leave the area during maintenance or monitoring, but because these activities would not be continuous (i.e., may be weekly or monthly and not hourly or more frequent), affected biota may be expected to return following completion of the monitoring or maintenance activity. However, should maintenance or monitoring identify concerns such as with a pipeline (e.g., pipeline monitoring identifies unacceptable level of corrosion) or waste storage facility (e.g., integrity concerns for on-site disposal pits for drilling muds), measures to address those concerns may require replacement or repair, which could result in additional environmental impacts. In such an event, impacts would be similar in nature to those identified for construction (related the habitat loss, noise, and disturbance), but would likely be of lesser magnitude because some of the resources (i.e., habitat) would have previously been disturbed during facility construction.

6.2.5.4 Accidental Spills and Releases

Accidental releases of oil, drilling and production wastes, and processing wastes may expose wildlife and their habitats to contaminants that may adversely affect growth, reproduction, and survival. Accidental releases may also result in the deposition of oil or oil residues on shoreline or wetland nesting habitats of some birds, as well as habitats utilized by some birds for feeding (such as beaches used by shorebirds). Releases from offshore wells and pipelines may affect wildlife and their habitats not only in the vicinity of the release but also in other areas where currents may transport the released materials.

Exposure to the released materials may result in acute or chronic toxic effects, reducing survival, growth, and reproduction. Local or regional population-level effects may result if, following ingestion of contaminated food or incidental ingestion of contaminated media (sediments or soil), reproduction is affected (e.g., reduced egg production and increased malformations of embryos). Oil that is not subsequently removed may remain on or in the habitats for extended periods of time, resulting in chronic exposure of some biota through direct contact and uptake or through the food chain. Depending on the magnitude of the release, the speed with which the release is contained, the effectiveness of the cleanup, the location of the release or spill, and the species and life stage (egg, young, or adult) exposed, exposure to a spill or release could result in local or regional population-level effects.

6.3 POTENTIAL EFFECTS ON THREATENED AND ENDANGERED SPECIES

Species listed as threatened or endangered under the ESA, as well as other species similarly listed by state statutes, could be adversely affected by each of the three phases of oil and gas development. Approximately 172 species have been classified under the ESA as threatened or endangered in the eight Great Lakes states (Table 5.7). Among these species, 50 occur in habitats in or near coastal areas where onshore oil and gas well sites to access potential offshore resources might occur (Table 6.7). In addition to these Federally listed species, there are many more species listed by the individual states that could be affected in an identical manner.

TABLE 6.7 Number of Federally Listed Threatened and Endangered Species That Could Be Affected by Oil and Gas Development

Taxonomic Group	NY	PA	OH	MI	IN	IL	WI	MN
Plants	1	–[a]	2	8	2	3	4	–
Terrestrial invertebrates	1	–	3	3	1	2	2	–
Aquatic invertebrates	–	2	3	3	3	–	2	–
Fish	–	-	–	–	–	–	–	–
Amphibians	–	–	–	–	–	–	–	–
Reptiles	1	1	2	1	–	–	–	–
Aquatic birds	2	2	2	2	2	3	2	2
Terrestrial birds	–	–	–	1	–	–	–	–
Mammals	1	–	1	2	1	1	1	2

[a] A dash (–) indicates no species of that taxonomic group identified for the state.

Some of the Federally listed species occur within some of the Great Lakes Basin states as occasional visitors or migrants, while others have known populations, nesting areas, or winter roost sites. For example, the Federally threatened piping plover is listed in each of the Basin states, but it has known breeding areas within the Basin only on beaches along northern Lake Michigan and Lake Superior in Michigan (USFWS 2005). In other areas of the Basin, this species is a transient visitor. In contrast, species such as the Federally endangered Michigan monkey flower are endemic to the Basin and are found only in some coastal counties of Michigan along the northern coast of Lake Michigan and the northwestern coast of Lake Huron. While exploration and construction would not be allowed where listed species are present and may be affected, species with such restricted distributions, such as the Michigan monkey flower, and the Lake Erie watersnake may be especially at risk from accidental spills and releases and habitat alterations associated with the construction of the well site and associated infrastructure.

Potential effects would be similar to those previously identified for vegetation, fish, and wildlife (see Tables 6.1 through 6.6), namely exposure to accidentally released oil, gas, drilling and production wastes, and processing wastes; habitat alteration; and disturbance by noise and human activities (Table 6.8). In addition, listed plant species may be especially affected if

TABLE 6.8 Potential Effects on Threatened and Endangered Species from the Development of Oil and Gas Resources Located beneath the Great Lakes[a]

Development Phase	Nature and Cause	Duration and Extent
Onshore Development		
Exploration	For mobile species, avoidance of habitats because of increased noise and human presence.	Short-term, unless site selected for full development or the species is very sensitive to the presence of humans.
Construction	Disturbance or loss of habitat due to clearing and grading at the well site and along any new access roads and utility and pipeline corridors, potentially resulting in a reduced number of individual present in the area.	Long-term habitat loss within the facility and access road footprints, short-term and/or long-term within pipeline and utility corridors. Short- or long-term reduction in numbers, depending on habitat requirements of the species in the area.
	Avoidance of habitats because of construction noise and activity.	Short-term, until construction activities are completed.
	Establishment of invasive, non-native vegetation in areas disturbed by clearing and grading activities, thereby reducing the quality of important habitat or directly competing with the listed plant species.	Long-term if invasive vegetation becomes established and reduces habitat quality or directly competes with listed vegetation.
	Fragmentation of habitat from siting of wellhead; storage and processing facilities; and pipeline, access road, and utility corridor.	Long-term. Extent dependent on quality and areal extent of habitats that would be fragmented.
Operation	Wildlife species in nearby habitats may be disturbed by noise and human activities.	Long- or short-term depending on sensitivity of disturbed species.
Accidental Spill or Release	Exposure of species and their habitats to accidental releases of oil or drilling wastes during exploratory drilling, potentially affecting the growth, survival, and reproduction of exposed species and also habitat quality.	Short-term, pending rapid release containment and site cleanup. Potential long-term effects depending on cleanup effectiveness. Duration and magnitude of effects would depend on the toxicity of the released materials, the species and life stage exposed, the magnitude and duration of the release, and the condition and quality of affected habitats and biota. Potential population-level effects.

TABLE 6.8 (Cont.)

Development Phase	Nature and Cause	Duration and Extent
Offshore Development		
Exploration	Avoidance of habitats because of increased noise and human presence.	Short-term, unless site selected for full development or the species is very sensitive to the presence of humans.
Construction	Disturbance or loss of habitat from onshore clearing and grading at pipeline landfall, storage and processing facility, access road, and utility corridor locations, potentially resulting in reduced number of individuals present.	Long-term habitat loss within facility and access road footprints, short-term and/or long-term within pipeline and utility corridors. Short- or long-term reductions in numbers, depending on the habitat requirements of species in the area.
	Disturbance of nearby habitats from altered surface and subsurface hydrology and increased sedimentation during onshore construction activities.	Long- and/or short-term, depending on the types of habitats affected.
	Avoidance of area habitats because of construction noise and activity.	Short-term until construction activities are completed.
	Establishment of invasive, non-native vegetation in areas disturbed by clearing and grading of onshore facility locations, thereby reducing the quality of important habitat or directly competing with the listed plant species.	Long-term if invasive vegetation becomes established and reduces habitat quality or directly competes with listed vegetation.
	Fragmentation of habitat from siting of wellhead; storage and processing facilities; and pipeline, access road, and utility corridor.	Long-term. Extent dependent on quality and areal extent of habitats that would be fragmented.
Operation	No adverse effects expected. Offshore platforms extending above the lake surface could provide rest sites for listed bird species migrating across open waters of the lakes.	No adverse effects expected. Long-term rest sites until platform is removed.
Accidental Spill or Release	Exposure of shoreline habitats and species utilizing those habitats to accidental releases of oil or drilling wastes during exploratory drilling, thereby affecting survival, growth, and reproduction of exposed species and reducing habitat quality in the immediate area of the release.	Short-term, pending rapid release containment and site cleanup. Potential long-term effects, depending on cleanup effectiveness. Duration and magnitude of effects would depend on toxicity of the released materials, the species and life stage exposed, the magnitude and duration of the release, and the condition and quality of affected habitats and biota. Potential population-level effects.

[a] Assumes compliance with ESA and similar state regulations, restrictions, and requirements.

invasive vegetation becomes established in construction areas, spreads to adjacent habitats, and competes directly with listed plant species. Because of the protection afforded to Federal species by the ESA, and to state-listed species by state-specific species protection regulations and oil and gas permit stipulations and siting requirements, most of the effects identified in Table 6.8 may be considered very unlikely, although impacts that may occur can have very serious consequences for the affected species. Any proposals for oil or gas development in areas supporting ESA-listed species would undergo extensive review by the USFWS (and likely by appropriate state agencies) before any approval to proceed with exploration would be granted. Proposed development in areas containing threatened or endangered species or in areas where such species could be adversely affected would not be expected to be approved.

6.4 POTENTIAL EFFECTS ON CULTURAL RESOURCES

The determination of effects on cultural resources must be handled at the project-specific level. There is no meaningful way to quantitatively characterize, across such a large region as the Great Lakes, the probability of an oil or gas development encountering cultural resources. However, the likelihood would be rather high on the basis of the current numbers of recorded sites provided in Table 5.9 (Section 5.4.3) for coastal counties along the Great Lakes and the large numbers of shipwrecks. The types of cultural resources that could be present in the vicinity of a development site are described in Section 5.4. Literature searches and field surveys would likely be necessary to determine the presence or absence of cultural resources (i.e., archaeological sites, historic structures and features, including shipwrecks, and traditional cultural properties). Consultations with the appropriate SHPO and government-to-government consultations with affected Tribal governments would also be required under the NHPA, as amended, to assess the significance of resources present and the potential for adverse effects on those resources that have been determined to be significant.

Impacts on cultural resources would be associated with well installation during exploration and construction and with the construction of the well pad, pipelines, storage and processing facilities, access roads, and utility corridors (Table 6.9). In addition, accidental spills or releases could contaminate some resources, affecting the chemical or physical condition of the resource, as well as potentially affecting future analysis and characterization of the resource. In the event of an accidental spill or release, cultural resources could also be affected during spill containment and cleanup. The nature and duration of effects related to accidental spills and releases would depend on the extent of the release, the nature of the resource affected, and the type of activity that would be required to contain and clean the release.

Potentially adverse effects could occur if significant cultural resources are present in a given project area, whether it is located onshore or offshore. Coastal regions have been heavily utilized by different cultures throughout history, and therefore the potential for sites to occur in a given project area is relatively high. Ground disturbance, such as grading, excavating, or trenching, would have the most obvious and direct effect if an archaeological site or traditional cultural property is present in the area to be disturbed. These sites would be destroyed during the proposed activity. For historic buildings or sites with structural remains, the direct effect would be demolition and removal.

TABLE 6.9 Potential Effects on Cultural Resources from the Development of Oil and Gas Resources Located beneath the Great Lakes

Development Phase	Nature and Cause	Duration and Extent
Onshore Development		
Exploration	Destruction of artifacts or sites during drilling of exploratory wells.	Permanent, long-term. Likelihood of encountering artifacts unknown.
	Trampling of surface and subsurface artifacts and sites by vehicle and foot traffic during seismic surveys and exploratory drilling.	Short- or long-term, depending on nature of the resource.
	Identification of previously unknown resources.	Permanent, long-term.
Construction	Destruction of artifacts or sites during construction of drill pad, pipelines, access roads, and utility corridors, and during well completion.	Permanent, long-term.
	Trampling of surface and subsurface artifacts and sites by construction vehicles and foot traffic.	Short- or long-term, depending on the nature of the resource.
	Disturbance or loss of artifacts and sites from increased erosion because of altered surface hydrology.	Long-term.
	Visual disturbance of sacred locations; visual disturbance of overall cultural setting of a significant cultural resource (such as a historic home).	Short-term for impacts related to construction equipment.
	Interference with access to sacred sites.	Short- or long-term.
	Identification of previously unknown resources.	Permanent, long-term.
Operation	Visual disturbance of sacred locations; visual disturbance of overall cultural setting of a significant cultural resource (such as a historic home).	Long-term.
	Interference with access to sacred sites.	Short- or long-term.
Accidental Spill or Release	Exposure of resources from accidental oil release due to well blowout or pipeline leak, or release of extraction and processing wastes.	May alter the physical or chemical characteristics of the affected resource, potentially affecting future characterization. Spill containment and cleanup may also result in loss of some resources.
	Interference with access to sacred sites.	Short- or long-term.

TABLE 6.9 (Cont.)

Development Phase	Nature and Cause	Duration and Extent
Offshore Development		
Exploration	Destruction of artifacts or sites during drilling of exploratory wells.	Permanent, long-term.
	Identification of previously unknown resources.	Permanent, long-term.
Construction	Destruction of offshore and/or offshore artifacts or sites during construction of drill pad, pipelines, access roads, and utility corridors, and during well completion.	Permanent, long-term.
	Trampling of surface and subsurface artifacts and sites at onshore construction locations by vehicle and foot traffic.	Short- or long-term, depending on the nature of the resource.
	Disturbance or loss of artifacts and sites from increased erosion because of altered surface hydrology at onshore construction areas.	Long-term.
	Interference with access to sacred sites.	Short- or long-term.
	Identification of previously unknown resources.	Permanent, long-term.
Operation	Interference with access to sacred sites.	Short- or long-term.
Accidental Spill or Release	Exposure of resources from accidental oil release due to well blowout or pipeline leak, or release of extraction and processing wastes.	May alter the physical or chemical characteristics of the affected resource, potentially affecting future characterization. Spill containment and cleanup may also result in loss of some resources.
	Interference with access to sacred sites.	Short- or long-term.

For archaeological sites and traditional cultural properties in the vicinity of the directly disturbed area, other general, construction-related issues must be considered at the site-specific level. For example:

- Changing drainage patterns could cause erosion, thereby displacing artifacts and damaging the nearby site(s);

- Staging areas for equipment and supplies, as well as traffic lanes and parking areas, may compact a site(s), thus destroying and/or displacing artifacts or significant resources such as plants; more damage is likely if the area becomes wet and vehicles and equipment further disturb the surface (e.g., creating ruts

and depressions that could further displace artifacts and destroy possible features or other significant resources); and

- Pedestrian traffic and presence also could affect a surface archaeological site and increase the potential for collection of artifacts or vandalism (either illicit or unintentional).

The general placement of a project may affect a Tribal member's ability to access or view an important or sacred location. Additional visual impacts are possible if the project is in view of a significant cultural resource, such as a historic home, whereby the project affects the overall cultural setting.

Offshore development impacts could include physical damage to underwater archaeological resources, such as shipwrecks. These impacts would most likely occur during exploration or construction. Impacts to known resources can likely be avoided; however, there is a great potential for encountering unidentified and unrecorded underwater resources. Few underwater archeological surveys have been conducted, and, depending on the depth and location (and even weather conditions), surveys can be difficult and expensive to conduct. These unrecorded resources are likely to be the most susceptible to impact (see discussion that follows on unexpected discoveries).

For areas where no significant cultural resources have been identified through survey and appropriate consultations, there is a significant potential for encountering unexpected buried material (such as an unmarked human burial) either onshore or offshore during construction. In these instances of unexpected discovery, work should be halted immediately and the appropriate persons notified (e.g., SHPO or Tribal Preservation Officer), so that mitigative actions can be implemented. Workers should also be trained that if there is any doubt about whether an item is a cultural resource, it should be treated as if it is, and the appropriate persons should be notified. This practice is very important, since most individuals would not necessarily recognize, for example, debris from a fragmentary shipwreck.

Impacts on cultural resources associated with a spill would most likely occur as a result of cleanup operations, rather than from the spill itself. Several spill-specific and site-specific factors would determine the extent of the impacts (size of spill, type of equipment, number of people on cleanup crew, and proximity to cultural resource). The impacts would generally be the same as those described for construction, but without the ability to mitigate the impacts beforehand. In general, the appropriate persons should be immediately notified (as in unexpected discoveries), to determine if some mitigation measures can be employed without delaying cleanup efforts and to determine what course of action can be taken to recover data from an affected cultural resource.

Accidental spills or releases may also affect the chemical or physical condition of an artifact, potentially resulting in permanent damage or even loss of the artifact. Contamination in soils associated with an artifact or site could also affect some techniques used for characterizing the site, such as pollen grain analysis.

Mitigation of the potential direct effects of construction activities is possible, with avoidance of impacts being the preferred option. Impacts on archaeological sites and historic buildings and features can be mitigated through data recovery (either full or partial) as a least-preferred option. Mitigation of indirect effects can encompass a multitude of options, including avoidance (again preferred), erosion controls, fencing, training, monitoring, etc. Mitigation for impacts of concern to Native Americans would have to be addressed during government-to-government consultations.

6.5 POTENTIAL EFFECTS ON LAND AND WATER USE

6.5.1 Potential Effects on Land Use

Land use may be affected by (1) the conversion of land from a nonindustrial to an industrial use, (2) the disturbance of some land uses on adjacent lands by noise, air emissions, and the presence of equipment during construction and operation activities, and (3) an accidental spill or release that may prevent a designated land use on adjacent lands until containment and cleanup are completed. The magnitude and importance of any potential effect would depend on the existing use of the affected area and on the basis for the effects (i.e., land conversion).

Figure 6.5 Aerial View of Rattlesnake Canyon Habitat Management Area, New Mexico, Showing Well Pads and Access Roads

The installation of a production and storage facility and its associated infrastructure (disposal pits, pipeline, access road, and utility corridor) would likely require a change to an industrial use from some other use, such as timber production or agriculture. This would result in a relatively small but permanent change in land use at a local scale. However, aggressive oil and gas development may result in a mosaic of production facilities that could conflict with existing or planned land use in surrounding areas (Figure 6.5).

6.5.1.1 Recreational Land Use

The coastal and nearshore portions of the Great Lakes where oil and gas development may be possible contain a number of recreational areas, including four national lakeshores, two national parks, numerous state parks, and other tourist destinations (see Section 5.5.1). Visual impacts affecting recreational lands may occur during exploration, construction and operation, and waste storage. The presence of exploration and construction equipment, as well as a well pad and/or pipeline, can detract from the visual setting of certain “pristine” areas enjoyed for their natural state (Figure 6.6) and also high-use public areas such as beaches or resorts. The visual

impacts may be temporary (if associated with exploration or construction equipment, or with equipment associated with spill cleanup) or long term (associated with the presence of a well and pipeline), remaining for the duration of the well operating period (which may be 20 or more years). Noise generated during all phases of oil and gas development could disturb recreational users of nearby areas, decreasing the quality of their recreational experience. Other possible impacts on recreational land use could include placement of wellheads or platforms in areas of future recreational use, thereby limiting the full recreational potential of an area (e.g., preventing trail expansion).

Figure 6.6 Example of a Typical Producing Well Site in West Virginia (Source: Coleman 2005)

Many states have permit requirements that specify minimum locations of wells to recreation areas, specifically to address concerns regarding recreational land use impacts. These requirements act to minimize the likelihood or magnitude of impacts to recreational land use. For example, Michigan requires well sites to be sited so they are not visible from recreational beaches.

Accidental spills or releases have the greatest potential for affecting recreational land use. Onshore and offshore spills may affect the recreation experience by:

- Restricting use of the area affected by the release (e.g., closure of a beach or fishing area);
- Producing a visual intrusion (by the spill and associated containment and cleanup equipment); or
- Indirectly affecting wildlife or habitats that are targets of a recreational fishery or hunting.

Such effects may be short- or long-term in nature, depending on the site of the spill or release and the duration of subsequent cleanup.

6.5.1.2 Residential Land Use

Impacts on residential land use may also be visual in nature, even where individual private residences would not be directly affected by the well construction or operation. Residential areas may also be affected by noise and air emissions generated during construction and by operating wells and processing equipment. The presence of operating oil or gas wells and pipelines may reduce the desirability of nearby existing residential areas, as well as inhibiting the development of additional residential development, especially in expanding urban areas. Many

states have permit stipulations regarding how close to a residential area an oil or gas well may be located. Such state-specific requirements will act to reduce the likelihood or magnitude of impacts to residential land use.

6.5.1.3 Industrial Land Use

Because of the industrial nature of an oil or gas development, industrial land use is not expected to be affected by such a development. However, in the event of an accidental spill or release, some industrial activities may be affected. For example, an offshore spill may close a portion of a harbor to commercial ship traffic or an industrial water intake while the spill is contained and during cleanup. Similarly, should bottom sediments become contaminated, shipping activities may need to be halted while dredging occurs.

6.5.1.4 Agricultural and Forest Production Land Use

Impacts on agricultural land use are anticipated to be minimal because the amount of land that could be potentially taken out of future use by a well and its associated facilities would be relatively small in comparison with the overall amount of land acreage available and in use within the Basin for agricultural production. On a local scale, however, the establishment of a concentrated oil or gas development (such as that shown in Figure 6.5) may result in a relatively large loss of agricultural land. Placement of oil and gas wells and infrastructure may also interfere with continuity of fields, harvesting, or grazing. If construction of a well site and associated infrastructure (pipelines, access roads, and utility corridors) results in a local change in surface water and groundwater hydrologic regimes, agricultural production may be affected. An accidental spill or release may also affect agricultural production, especially if the spill or release contaminates area soils or an irrigation or livestock watering source.

Impacts on forest lands may also be relatively small for individual wells, while concentrated development sites may locally result in a relatively large loss of forest land. The presence of pipelines, access roads, and utility corridors may also fragment forest lands, affecting harvesting efficiency and forest tree species composition, while changes in hydrology and surface erosion may adversely affect forest production.

6.5.2 Potential Effects on Water Use

The primary affects on water use from onshore and offshore oil and gas development would be associated with (1) poor siting of offshore well platforms and pipelines that may interfere with recreational boating, fishing, and sport diving on shipwrecks, or with industrial shipping corridors; (2) accidental spills or releases that may prevent the withdrawal of water for public drinking water supplies, irrigation and livestock watering, manufacturing and industrial needs, or energy production; and (3) direct use of surface waters for recreational activities. Impacts associated with potentially poor siting may be long term. Impacts associated with spills may be short or long term, depending on the nature of the spill or release, its proximity to a water

intake structure, and the amount of time needed to contain and clean up the spill. Spills could disrupt public drinking water supplies as well as irrigation water; loss of use would depend on the materials released and the effectiveness of the spill cleanup. Because these waters would be used for human consumption or food production, much more stringent cleanup levels would likely be necessary before water use could be reestablished. In contrast, manufacturing and energy production may be less sensitive to water quality, and thus may not be affected for as long a time period.

Placement of offshore wells and pipelines may result in local restrictions on boating and fishing in the immediate vicinity of the well site, especially during drilling and construction. Such restrictions would be short term and would generally end with completion of well and pipeline construction. Burial of pipelines and wellhead protection measures should greatly relieve or eliminate the potential for collisions with watercraft. While anchoring restrictions along submerged pipelines may affect use of these areas for some fishing, the overall impact would depend on whether recreational fishing occurred along the pipeline route prior to its construction. Overall effects of such anchoring restrictions may be considered minor. Recreational water use, similar to recreational land use, may experience long-term effects from accidental spills. Spills may affect swimming and fishing areas and contaminate local fisheries. The duration and magnitude of such effects would depend on the nature and magnitude of the spill and the effectiveness of subsequent containment and cleanup.

The nature and extent of impacts to water use from accidental spills will depend not only on the magnitude of a spill, but also its location. For example, some areas of the Great Lakes, such as the northern portion of Lake Michigan (especially along the Michigan coastline), do not support any major urban industrial or energy-producing centers or facilities. However, this portion of the lake supports a strong recreation and tourism economy, with numerous small towns and resort areas throughout the coastal areas, many of which may rely more heavily on groundwater for drinking water supplies. In addition, inland areas support agriculture and forestry. Thus, water use for agriculture and recreation may be most affected by an accidental spill or release.

In contrast, other areas, such as the central and eastern basins of Lake Erie include major urban and industrial centers (e.g., Cleveland and Buffalo), numerous coal-fired and hydroelectric power plants, a nuclear power plant, and agricultural lands. Many of these rely heavily on water withdrawn from Lake Erie. While recreational water use may not be as predominant as in other areas of the Great Lakes, recreational boating is often strong in the vicinity of major urban centers. Thus, all water uses in these basins of Lake Erie could be affected by accidental spills or releases. In addition, an accidental spill or release in such an area has the potential to affect more users because of the high population densities of urban centers compared with more rural areas of the basin.

6.5.3 Potential Effects on Economically Important Zones

Potential effects of oil and gas development on economically important zones of the Great Lakes would be primarily associated with accidental oil spills or releases that would affect

normal economic activities, such as shipping, manufacturing, or tourism. Along the northwestern shore of the lower peninsula of Michigan is an area that supports an extensive recreation and tourism economy. Tourism and recreation in such areas as Sleeping Bear Dunes National Lakeshore, Grand Traverse Bay, Petoskey, and the Mackinaw Straits could be affected by offshore oil spills. In the event of a spill, short- or long-term impacts on the economies of these areas could be incurred, depending on the magnitude of the spill and how quickly and effectively the spill is contained and cleaned up. Because an offshore spill would be more visible, more difficult to contain, and could affect highly visible beaches and dunes, spills from offshore wells and pipelines may be expected to have a greater potential effect than spills at onshore locations. Similar effects on tourism and recreation could be incurred on the upper coast of Lake Huron as well as along the lower peninsula of Michigan. No major ports or industrial centers are located along the northern coast of Michigan.

All three basins of Lake Erie support a wide range of economies. The western basin includes the major ports of Detroit and Monroe in Michigan, and Toledo, Ohio. The central basin includes the major ports of Lorain, Cleveland, Ashtabula, and Conneaut in Ohio, and Erie in Pennsylvania, while the eastern basin includes Buffalo, New York. In addition, Cleveland and Buffalo represent major industrial and manufacturing centers. While the construction and operation of onshore or offshore oil and gas wells in the vicinity of these areas is not expected to affect shipping and manufacturing, oil spills in these areas could result in short- or long-term impacts on the various economic activities in the lake. However, directional onshore wells or offshore wells may be expected to largely target natural gas rather than oil, and accidental releases of natural gas would likely result in only short-term, localized, and minor disruptions to the shipping, manufacturing, or industrial economies of the lake. Shipping and water withdrawals for manufacturing and industry use would likely not be affected by accidental gas releases.

While Lake Erie supports both recreation and tourism economies in all, the major recreation and tourism zones in Lake Erie are associated with the islands near Sandusky, Ohio, in the western basin of the lake and Presque Isle at Erie, Pennsylvania. While accidental releases of natural gas may be expected to result in only short-term, very localized, and minor disruptions to the recreational and tourism economies in many areas of the lake, releases or spills in these major recreation and tourism areas may result in major impacts on the economics of the islands and surrounding areas.

6.6 POTENTIAL INTERACTIONS WITH CONTAMINATED AREAS

Development of oil and gas resources beneath the Great Lakes may interact with existing areas of contamination within the lakes, primarily through the disturbance and mobilization of contaminated sediments or soils during well and pipeline construction. Depending on the placement of wells and the routes selected for any associated pipelines, some locations may overlie contaminated sites that are currently present in the lakes.

Many contaminated sites within the Great Lakes are located in AOCs, which are designated severely degraded geographic areas within the Great Lakes Basin (GLIN 2005a). The

U.S. and Canadian governments have identified 43 such areas, 26 of which are in U.S. waters (see Section 5.6.1). Most of the AOCs are near the mouths of tributaries where cities and industries are located (Figure 5.17). Several of the areas are along the connecting channels between the lakes. Pollutants are concentrated in these areas because of long-term accumulation of contaminants deposited from local point- and non-point-sources and from upstream sources. Nearly all the AOCs have contaminated sediments (EPA and Government of Canada 1995). There are seventeen AOCs in areas of the Great Lakes where oil and gas development may be feasible (northern Lake Michigan, and Lakes Huron and Erie) (Figure 5.22).

Potential interactions with contaminated sites could occur if oil and gas development is carried out within the AOCs that have not yet been delisted. The Ashtabula River AOC is one such example. The Ashtabula River lies in northeast Ohio, flowing into Lake Erie's central basin at the City of Ashtabula. Its drainage basin covers an area of 137 mi^2 (355 km^2), with 8.9 mi^2 (23.0 $km^{2)}$ in western Pennsylvania. From the 1940s through the late 1970s, unregulated discharges and mismanagement of hazardous waste caused the river's sediments to become seriously contaminated and degraded its biological communities. Regular dredging is being prevented because of the contaminated sediments, seriously impeding both commercial and recreational navigation. Since 1983, a fish consumption advisory has been posted for the AOC. Environmental problems have been caused by sedimentation, cultural eutrophication (nutrients), toxic substances (PCBs, heavy metals, and chlorinated organic compounds), and habitat modification (marina construction and commercial shipping). Sources for these contaminants include bottom sediments, municipal and industrial discharges, commercial development, hazardous waste disposal sites, CSOs, Fields Brook discharge, coal handling facilities, and rail yards.

Contaminated sediments within an AOC would be disturbed by exploratory drilling, well installation, and lake-bottom pipeline construction if the drilling and pipeline locations occur within the AOC boundaries. The disturbed sediments could be mobilized and transported by lake currents or wave action to other locations, potentially including shoreline areas. However, it is unlikely that exploration or well development would be permitted in such areas.

6.7 POTENTIAL HUMAN HEALTH EFFECTS OF ACCIDENTAL RELEASES

Considerable public controversy has arisen over potential environmental and safety risks from U.S. and Canadian offshore and directional oil and natural gas drilling in the Great Lakes. To date, there have been few reported problems (IJC 2002). Nevertheless, some believe that the risks involved in allowing oil and gas exploration companies to conduct directional drilling beneath the Great Lakes outweigh the benefits that would accrue to the public (Jenson 1998).

Two issues that state environmentalists and lakeshore property owners have been extremely concerned about relate to accidental releases (Jenson 1998). The first issue concerns whether anyone can be absolutely sure that a break in an underground pipeline or a crack in rock formations, causing oil or natural gas to seep into the lakes, would not cause irreparable damage. The second issue arises from having wellheads located so close to the Great Lakes; with the

shoreline as a focal point of recreation and tourism, there is a fear that accidental release of H_2S ("sour gas") or other gases may cause large-scale accidents (Jenson 1998).

In 1997, Governor John Engler requested that the MESB conduct an evaluation of the state's regulatory procedures pertaining to directional drilling under the Great Lakes. The panel concluded from a review of available data that there is little to no risk of contamination to the Great Lakes bottom or waters through releases directly above the bottom-hole portion of directionally drilled wells into Niagaran Reef and deeper reservoirs (MESB 1997). They also concluded, however, that there is a small risk of contamination at the wellhead. On the basis of the panel's finding that there exists a greater risk for potential impacts to the shoreline environments where the wellhead and its associated infrastructure are located than to the aquatic environment of the Great Lakes, the panel identified two areas of potential environmental concerns — ecological and social-aesthetic — that could be associated with, and consequently in conflict with, directional drilling on the Great Lakes' shoreline.

The MESB (1997) report defined the social-aesthetic impacts to include "quality of life" parameters, such as noise, odors, congestion, vistas, recreation, and tourism, which may affect physical and mental health, at least indirectly. Although the MESB panel did not focus on specific human health effects from accidental releases, there are still some concerns that may arise from directional drilling, including explosions, leaks, air quality, and seismic activity.

The final programmatic environmental impact statement (PEIS) for the development of Lake Erie natural gas resources modeled four accident scenarios for offshore gas development (USACE 1982). This study found that releases of petroleum-related hydrocarbons, raw natural gas, and polyethylene glycol could occur during accidents. The postulated accidents that could produce these releases were (1) loss of well control, (2) rig or barge capsizing, (3) gas-line breakage, and (4) glycol-line breakage (USACE 1982). The report concluded that occurrence of these accidents would be highly unlikely. Furthermore, the potential health risk associated with accidental release of di- or triethylene glycols, associated with trihalomethanes that may be formed during chlorination of a public drinking water supply, would not exceed the primary drinking water standards (USACE 1982).

The Lake Erie PEIS concludes that an accidental gaseous release from an explosion and fire at a gas treatment plant or from the rupture of an 8-in. (20-cm) gas flow line could have a potentially deleterious effect on the general public because of combustion products (USACE 1982). Although the specific impact of this type of event was not quantitatively assessed, it was expected that it would require residents to be evacuated.

In the absence of wind or rain, the rupture of an 8-in. flow (20-cm) line carrying H_2S gas would also require the evacuation of all people within 1,640 ft (500 m) of the break to avoid the toxic effects of the gas (USACE 1982). In addition, a larger area would probably be voluntarily evacuated by anyone in the area, to avoid the unpleasant smell of H_2S gas.

The extraction process raises significant concerns over public and occupational health and safety (Smith et al. 2002). Well blowouts are rare but can be quite serious. When the drill encounters an unusually pressurized zone or when equipment is removed from the hole, the

pressure exerted by the formation may rise to levels considerably higher than those exerted by the drilling or work-over fluid, causing such fluid to rise uncontrollably to the surface. Blowouts can completely destroy rigs and kill nearby workers. Likewise, explosions and leaks are known to have occurred in pipelines that transport fossil fuels (Smith et al. 2002).

Hydrogen sulfide, which may be released during the drilling process, is a highly toxic gas that can pose serious human health risks if present at sufficient concentrations (Smith et al. 2002). At a 1997 convention of the American Public Health Association, a number of scientists presented information about the dangers of "sour gas" exposure, which range from depression and extreme fatigue, to memory loss, brain damage, and death (Smith et al. 2002). Possible occupational exposure to H_2S for drill rig workers would also need to be monitored and mitigated. However, it should be noted that the presence and concentration of H_2S is formation-specific, that is, it is almost always spatially restricted to certain geological settings conducive to its subsurface and retention until accessed via drilling operations. These areas can be mapped by using well and seismic data with a relatively high degree of reliability

Drilling operations typically produce significant air emissions, including exhaust from diesel engines and turbines that power the drilling equipment, and from post-extraction treatment (Clark and Dutzik 2002). Pollutants from these sources are those commonly associated with combustion sources, including nitrogen oxides, particulates, ozone, and carbon monoxide. Each new well brings drilling rigs, gas compressors, generators, surface-disturbance machinery, such as earthmoving machines, and vehicular traffic (Smith et al. 2002).

Routine drilling wastes, such as drilling muds and cuttings, contain a variety of toxic chemicals that are known to be hazardous to human health (see Sections 2.2.1, 2.3, 3.4, and 3.5). If pollutants from oil and gas drilling build up in the food chain, people who consume fish from the Great Lakes could be at risk of health problems such as genetic defects and cancer. Routine discharges and accidental spills of toxic chemicals from drilling sites can also contaminate the water of Lake Erie, thus contaminating a primary drinking water source for millions of people (Clark 2003). From 2003 to 2008, the Great Lakes coastal population as a whole is expected to increase by approximately 650,000 people; the largest population increases are expected to occur in southern Michigan, Illinois, and Ohio (Crossett et al. 2004). Consequently, there is the potential for more people to be exposed to contaminants in drinking water from Lakes Michigan and Erie.

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